Trigger, reconstruction and physics performances in LHCb

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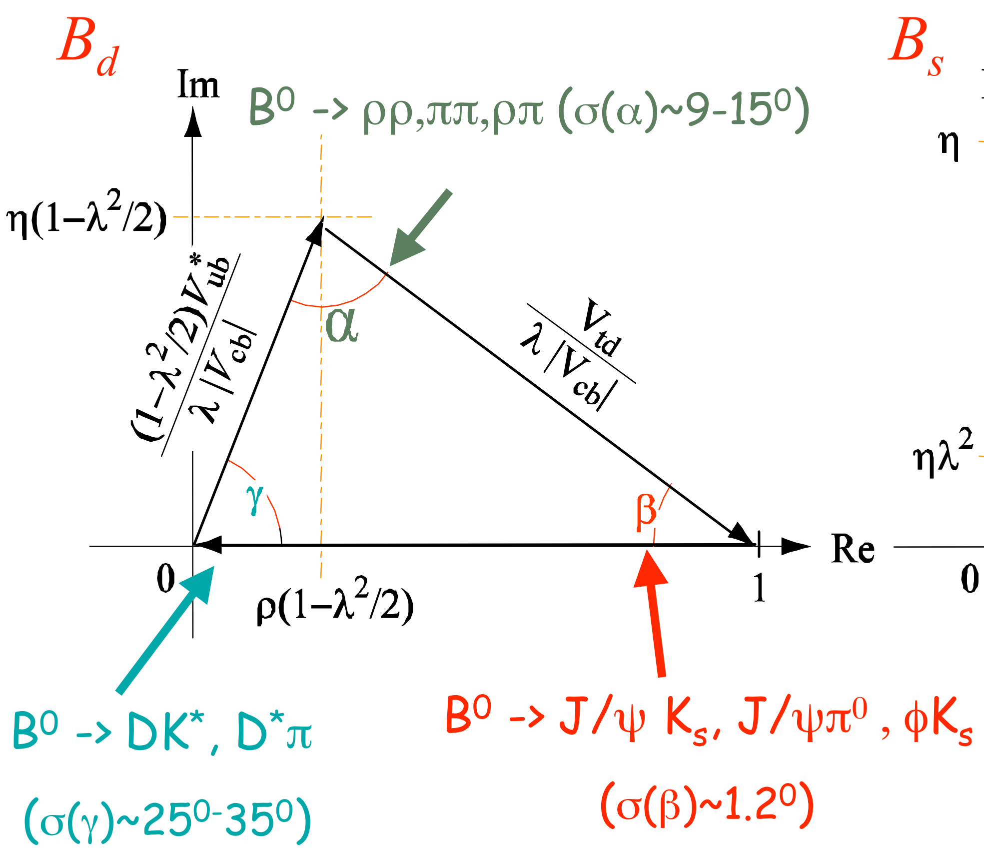
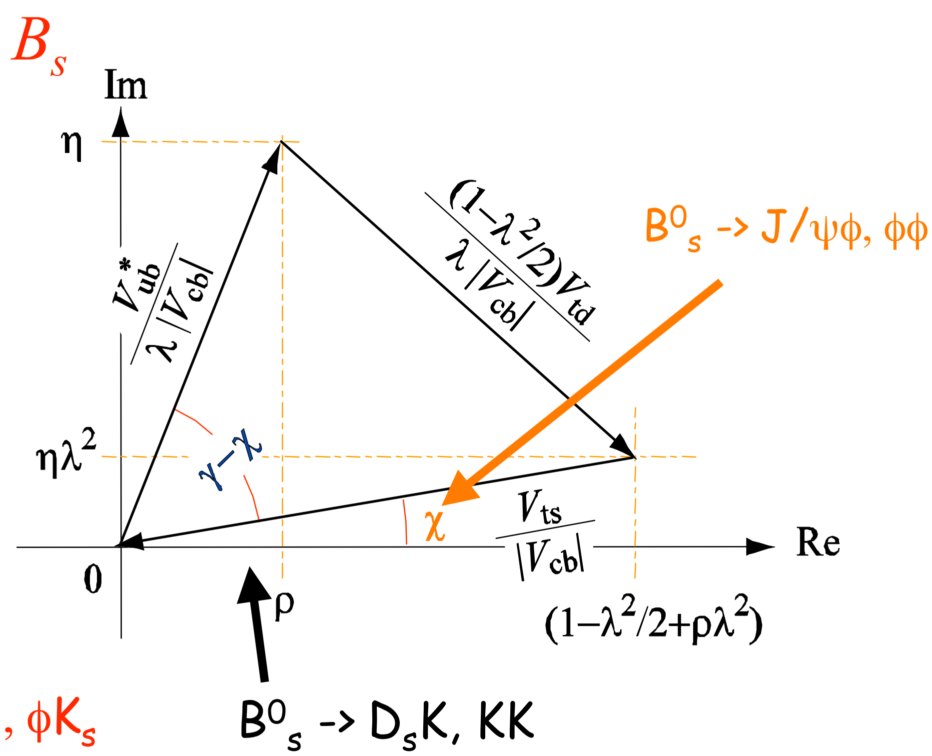
(on behalf of the LHCb Collaboration)

Physics motivation





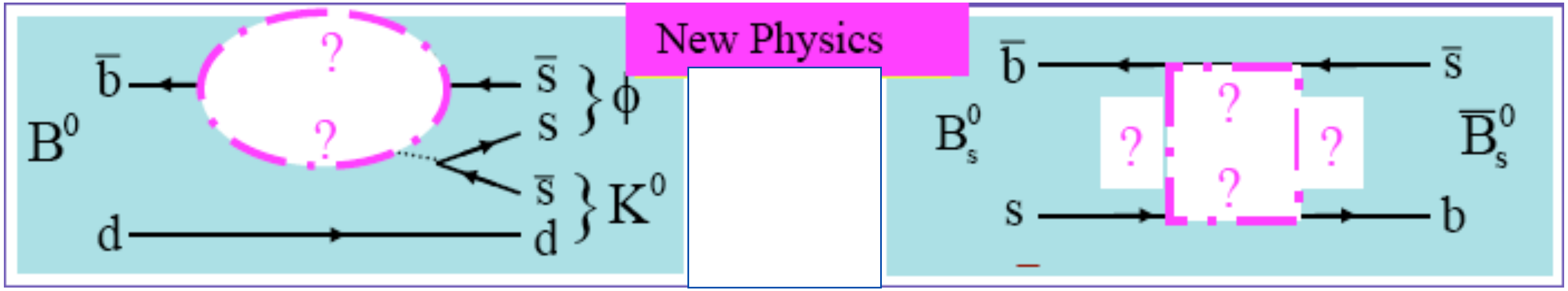
Current sensitivities from b-factories

CDF/D0: Δm_s measurement, observation of $B_s \to \phi\phi$

LHCb will study all types of B mesons with excellent precision

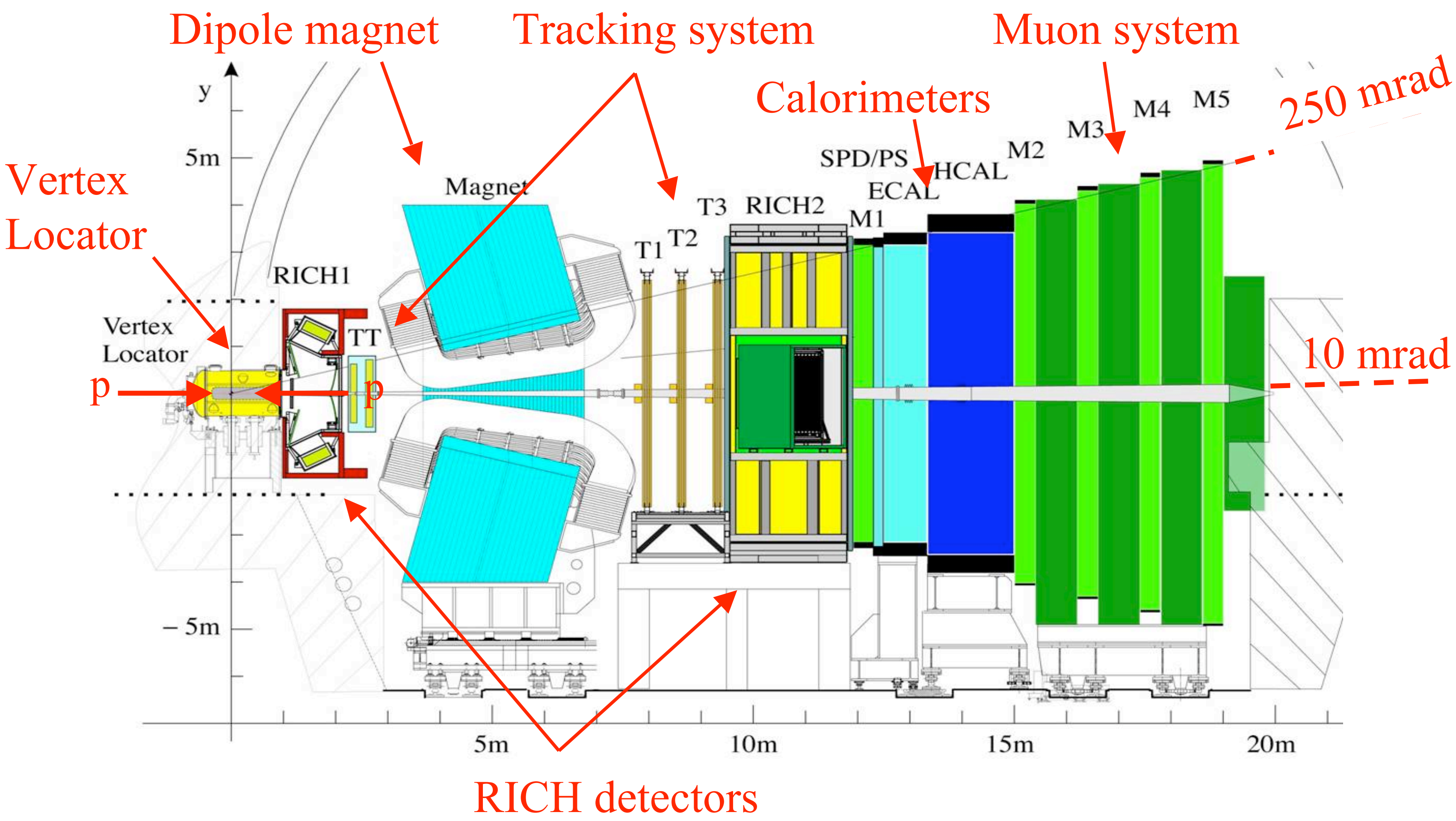
New physics

- *Standard model is a low-energy effective theory of a more fundamental theory at higher energy scale (TeV range)*
- *New physics can be discovered and studied :*
  - *Direct observation: new physics produced and discovered as real particles*
  - *Indirect approach: new physics appear as virtual particles in loop processes*



- *Observable deviations from SM expectations in flavour physics and CPV*
- *LHCb designed to make precision measurement of CPV and rare decays in B system*

The LHCb detector

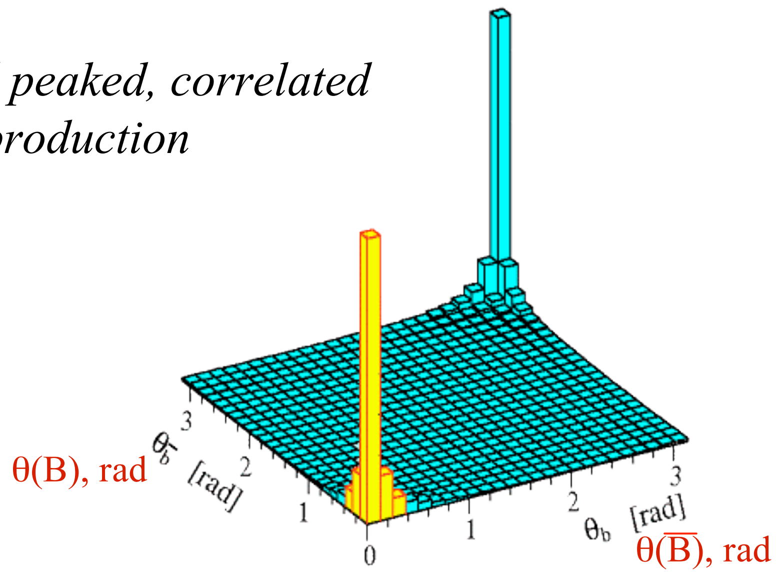


Details of the detector: see B.Pietrzyk

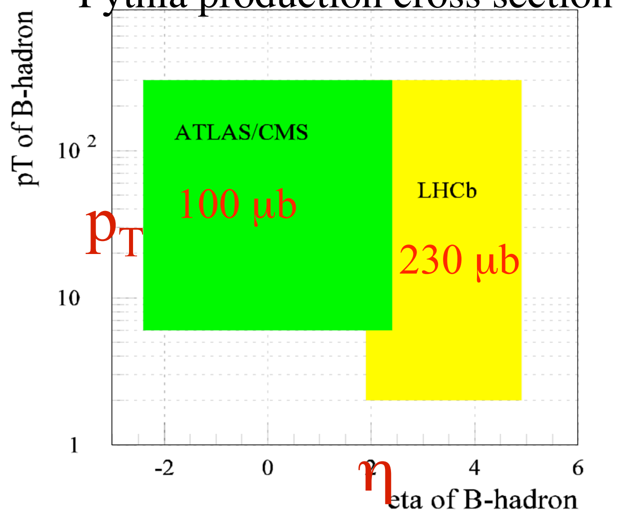
LHCb environment

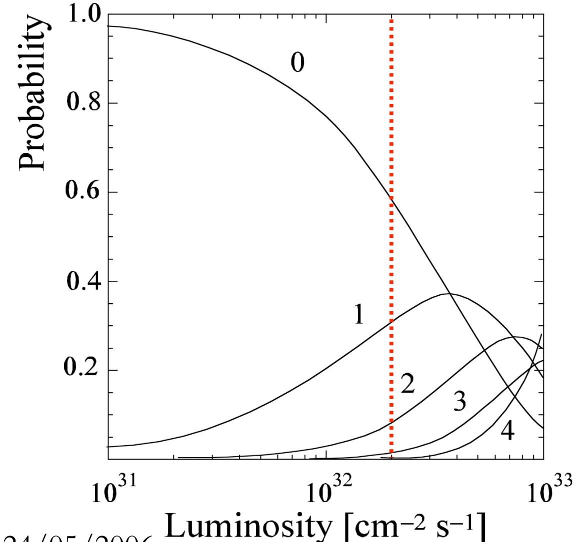
LHCb is a forward spectrometer (10-300 mrad)

Forward peaked, correlated bb pair production



Pythia production cross section





$\sqrt{s}$ = 14 TeV, *pp collisions: large* $\sigma_{bb} \sim 500\ \mu b$

but $\sigma_{bb}/\sigma_{tot} \sim 5\text{x}10^{-3}$

Interesting B decays have low BR $\sim 10^{-5}$

LHCb average $\mathcal{L} \sim 2 \times 10^{32}$ cm^{-2}s^{-1}

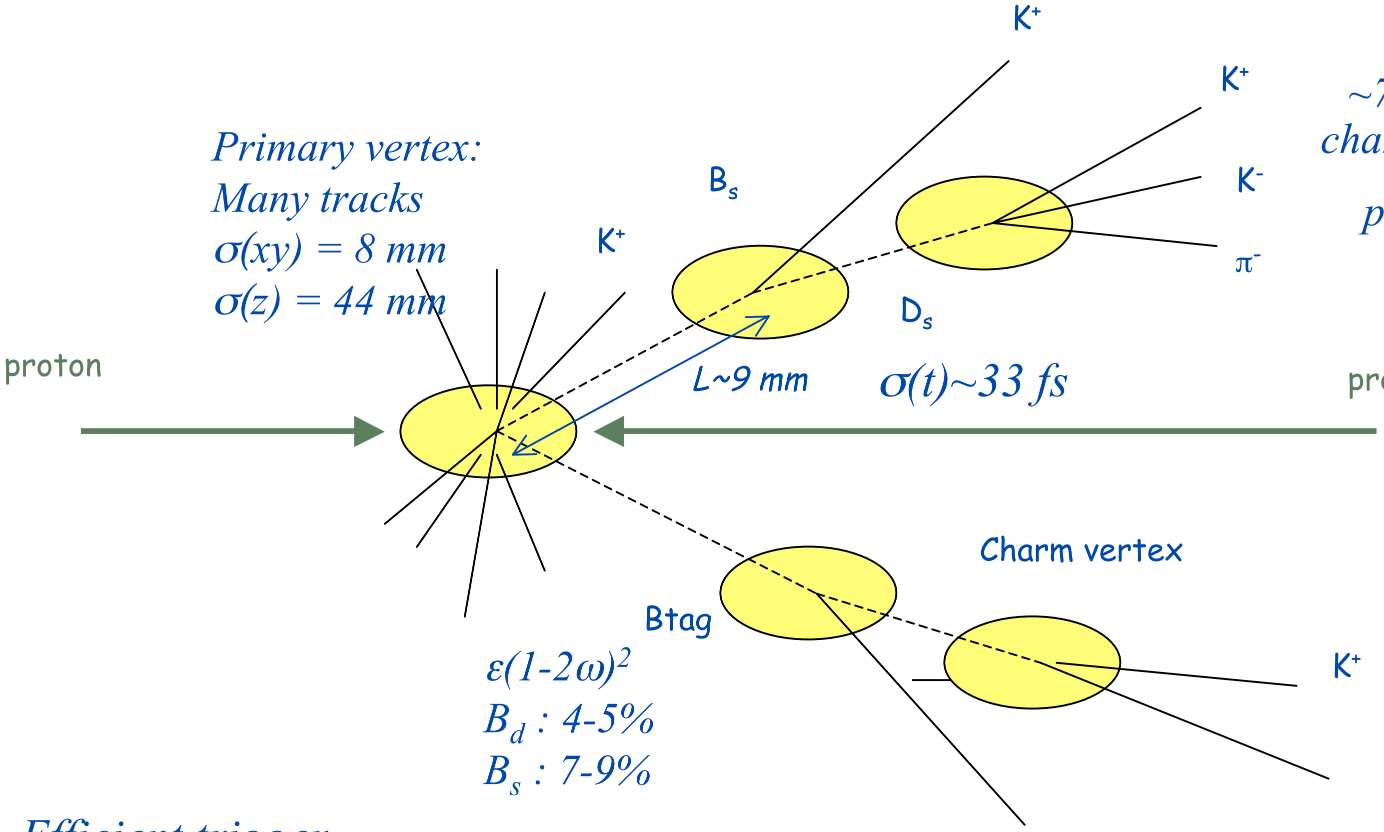
$\rightarrow$ 2 fb^{-1} / year (10^7 s)

$\rightarrow 10^{12}$ bb *produced/year*

most events due to single interactions per bunch crossing

A typical LHCb event

Primary vertex:
Many tracks
$\sigma(xy) = 8$ *mm*
$\sigma(z) = 44$ *mm*



~72 reconstructed charged tracks /event

p ~1 to 100 GeV

$\delta p/p \sim 0.37\%$

$\sigma(t) \sim 33$ *fs*

$\sigma(IP) \sim 20\mu m$

$\varepsilon(1-2\omega)^2$
B_d : 4-5%
B_s : 7-9%

Efficient trigger
Excellent tracking and vertex finding
Particle identification
Excellent resolutions

$\sigma(M_D) \sim 6$ *MeV*
$\sigma(M_B) \sim 14$ *MeV*

Trigger overview

40 MHz

↓

Level-0:
p_T of
μ, e, h, γ

← Calorimeter
Muon system
Pile-up system

↓

1 MHz

L0: custom hardware

↓

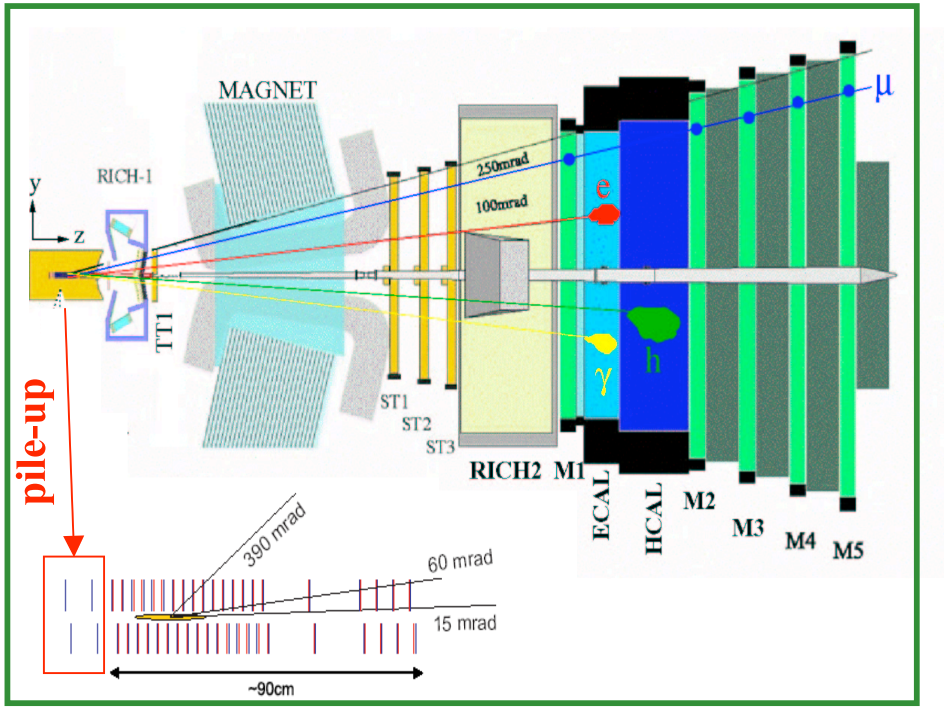
HLT:
Confirm level-0
Associate Pt/IP
μ, e, h, γ alley
Inclusive/exclusive
selections

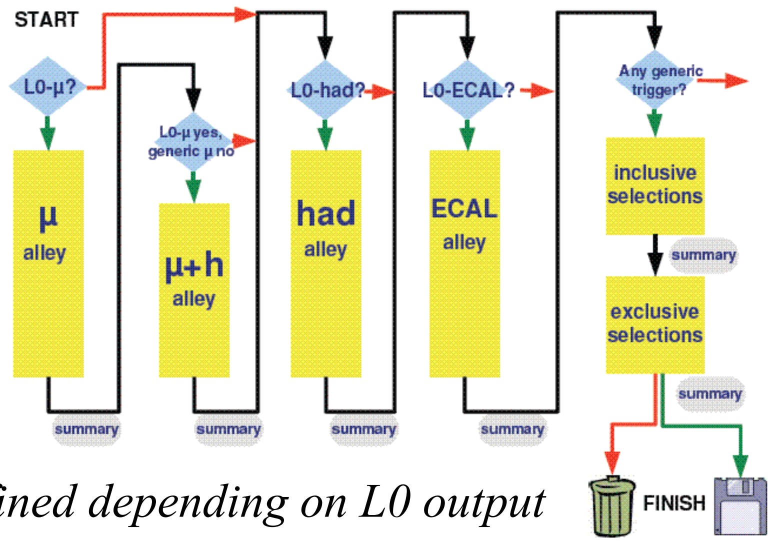
← Full detector
information

HLT: CPU farm

↓

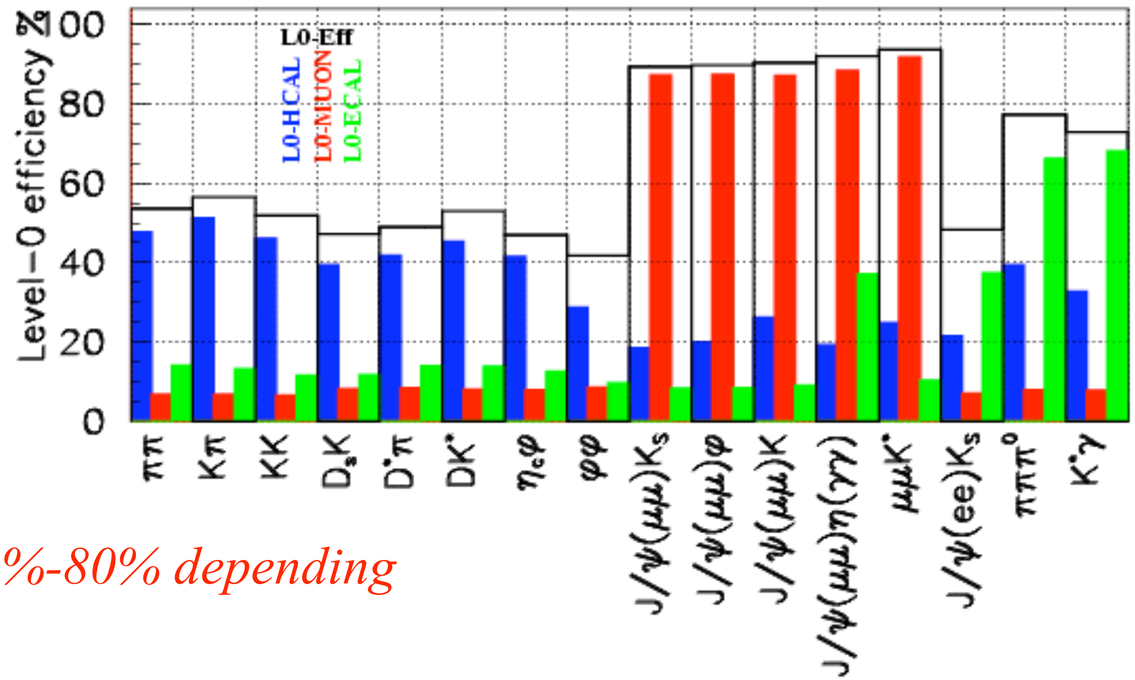
2 kHz output to tape





HLT: 4 independent alleys defined depending on L0 output

Trigger output



L0 efficiency
Hadronic dominated
Muon dominated
Ecal dominated

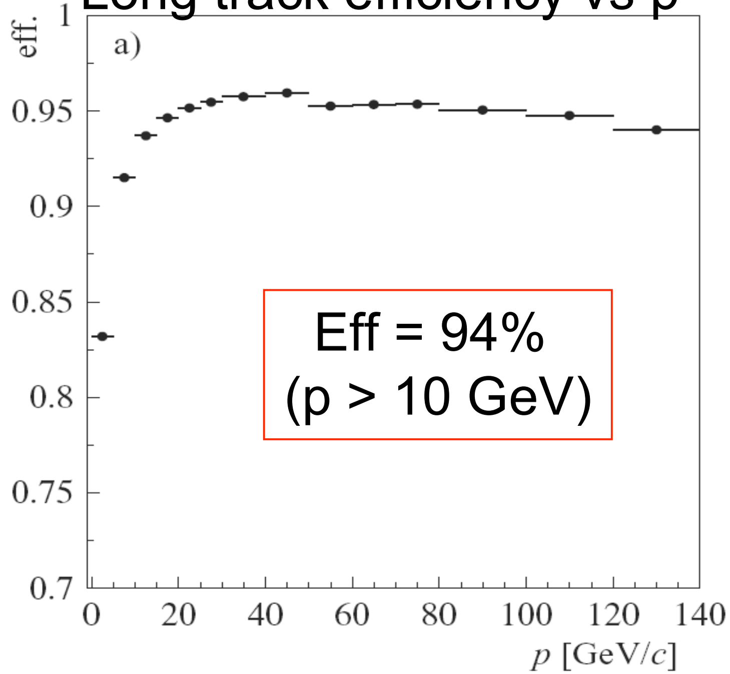
Overall trigger efficiency:30%-80% depending on signal channels

HLT Output rate	Trigger Type	Physics Use
200 Hz	Exclusive B candidates	Specific final states
600 Hz	High Mass di-muons	J/ψ, $b \to J/\psi X$
300 Hz	D* Candidates	Charm, calibrations
900 Hz	Inclusive b (e.g. $b \to \mu$)	B data mining

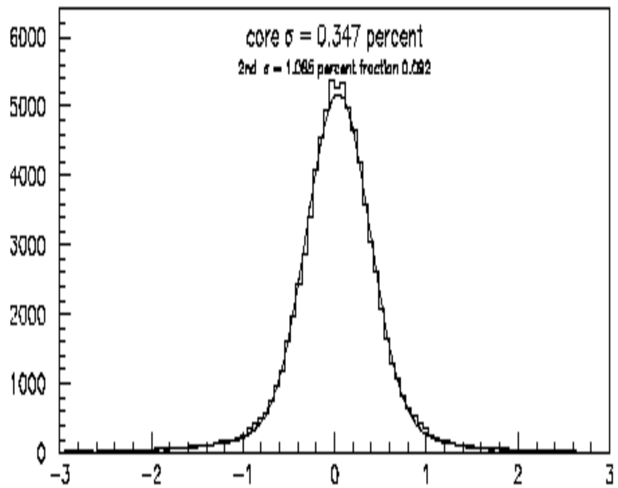
- *Rough estimate at present (split between streams still to de determined)*
- *Inclusive streams used for calibration and control of systematics*

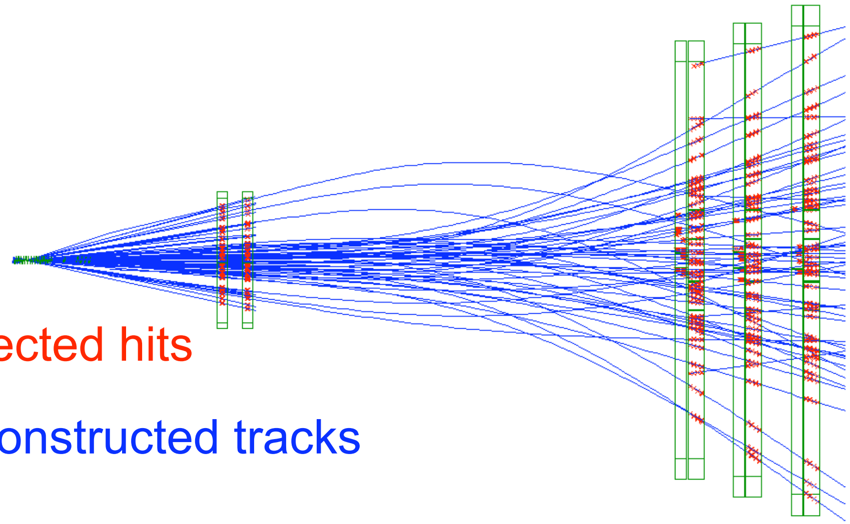
Tracking performance

Long track efficiency vs p



$\delta p/p \sim 0.37\%$



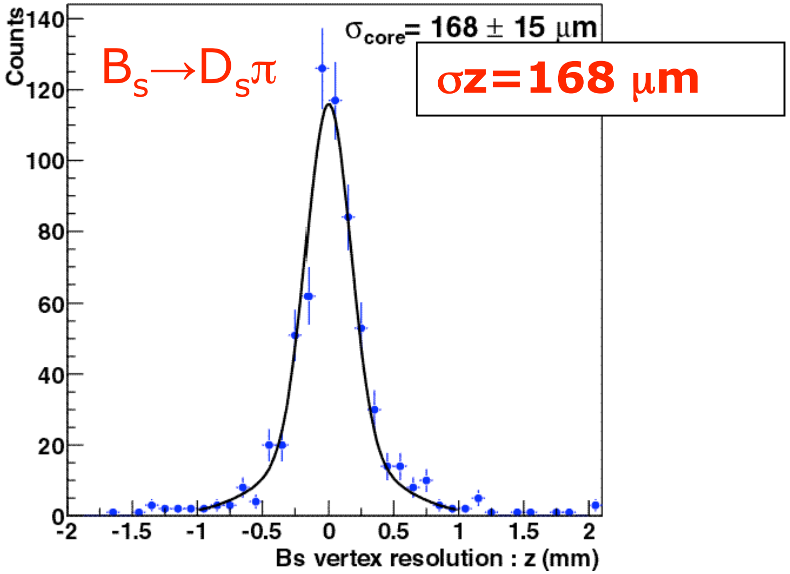


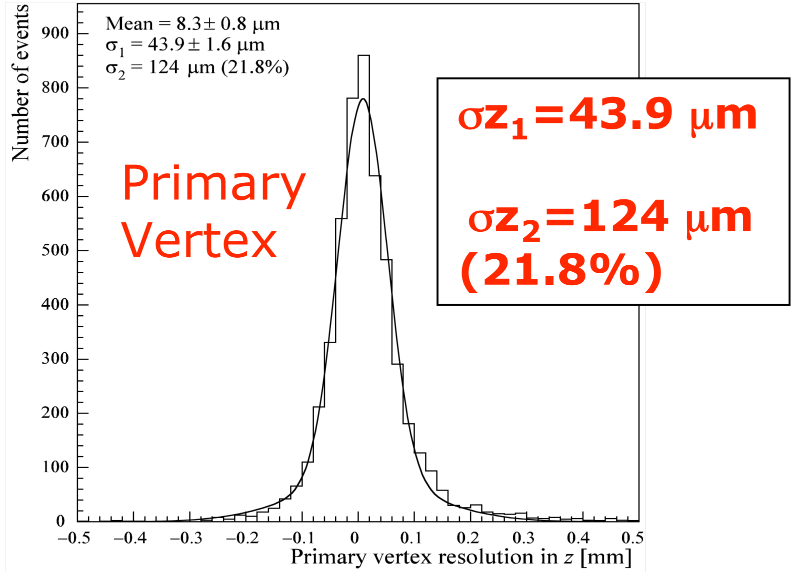
Red = detected hits

Blue = reconstructed tracks

<u>On average</u>:
26 long tracks
11 upstream tracks
4 downstream tracks
5 T tracks
26 VELO tracks

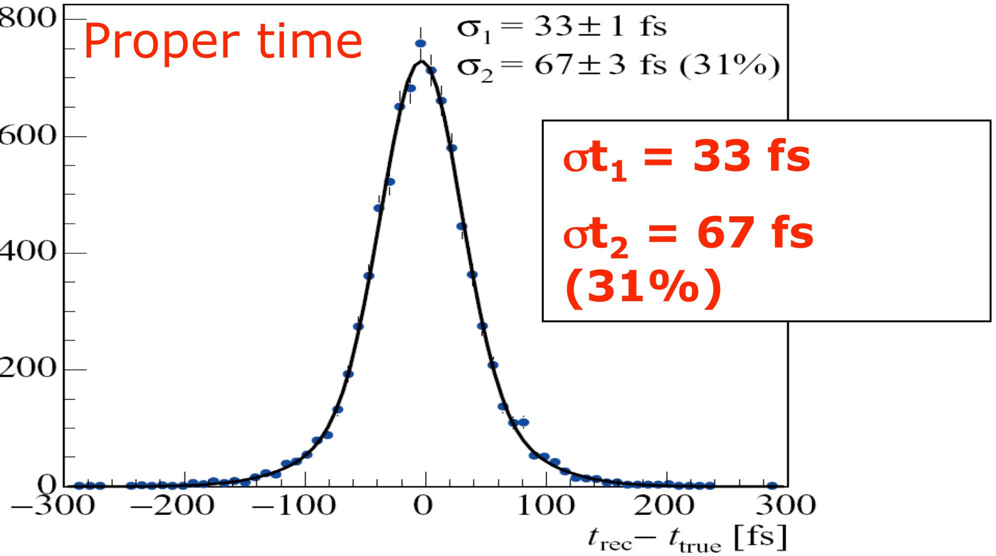
Vertex reconstruction





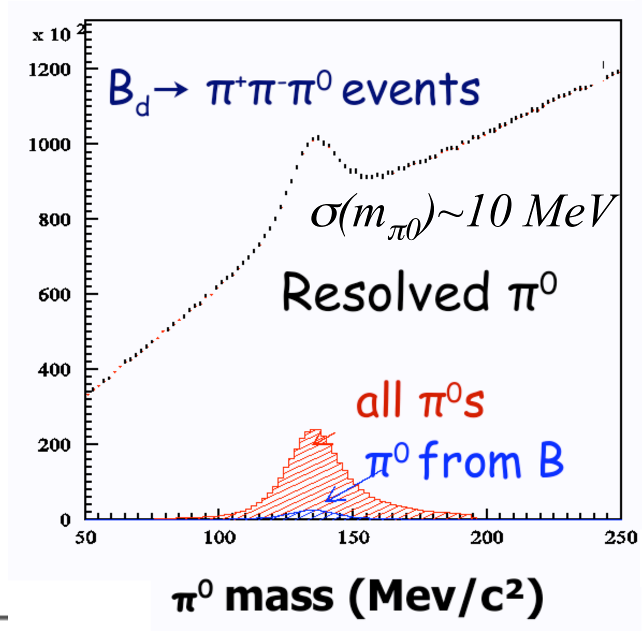
Proper time t=L×m/(p×c)

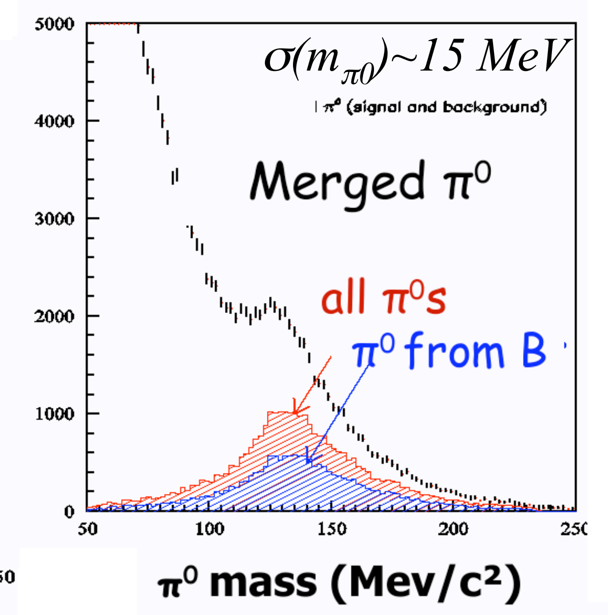
Proper time resolution is dominated by B vertex resolution

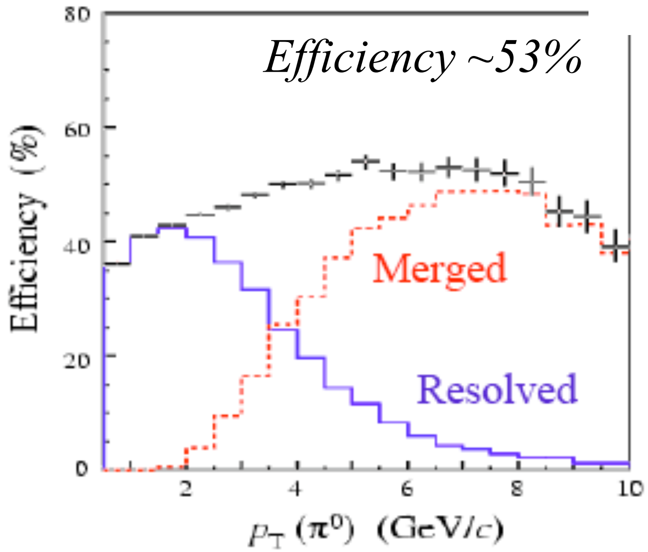


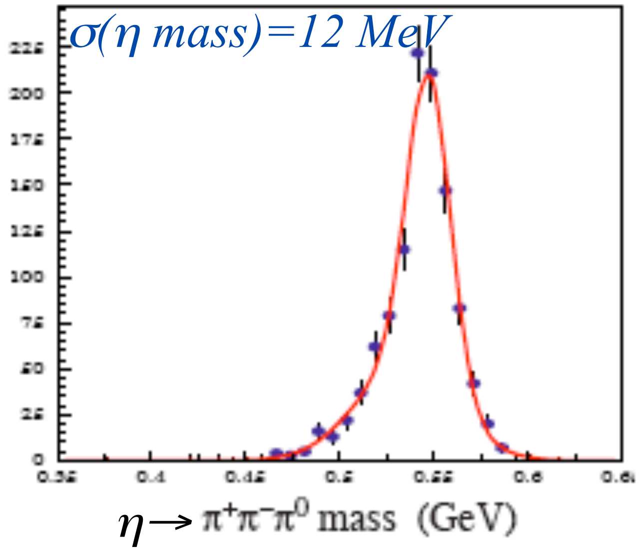
Neutral reconstruction

Good efficiency for π^0 in $B^0 \rightarrow \pi^+ \pi^- \pi^0$, using both resolved (separate clusters) and merged cluster shapes in the calorimeter

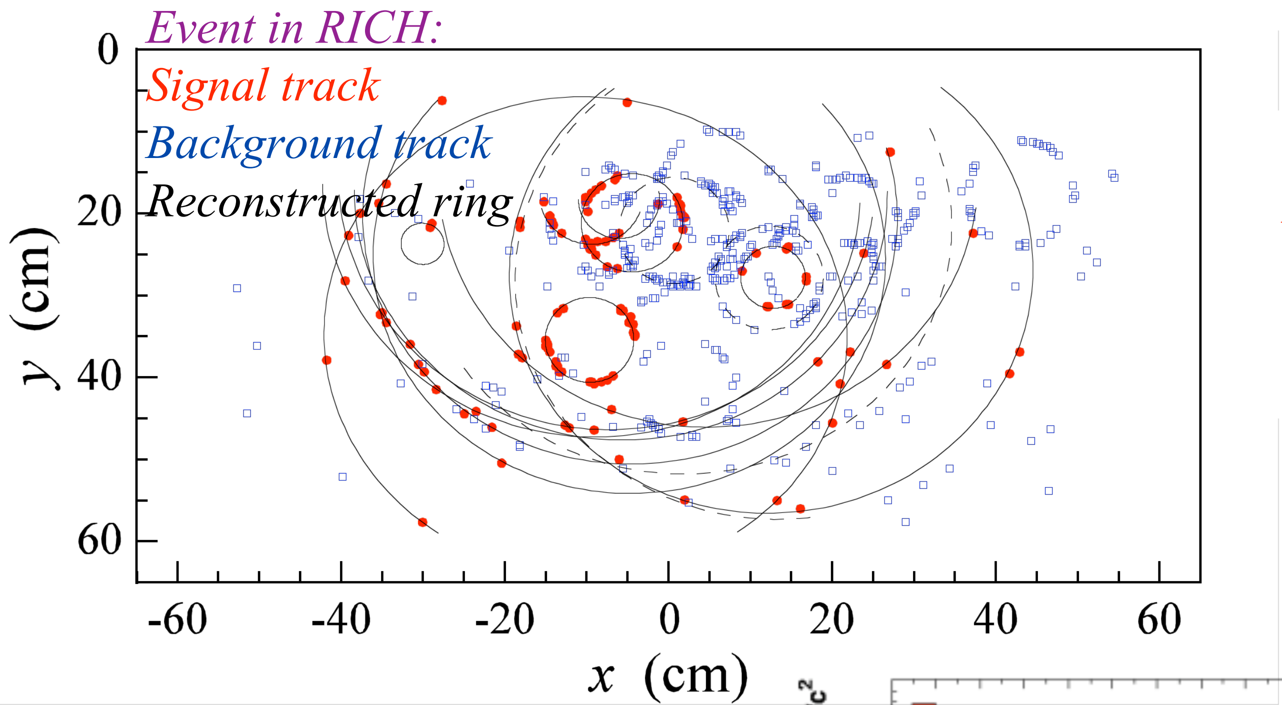








Particle identification



π/K separation provided by RICH for 2<p<100 GeV:

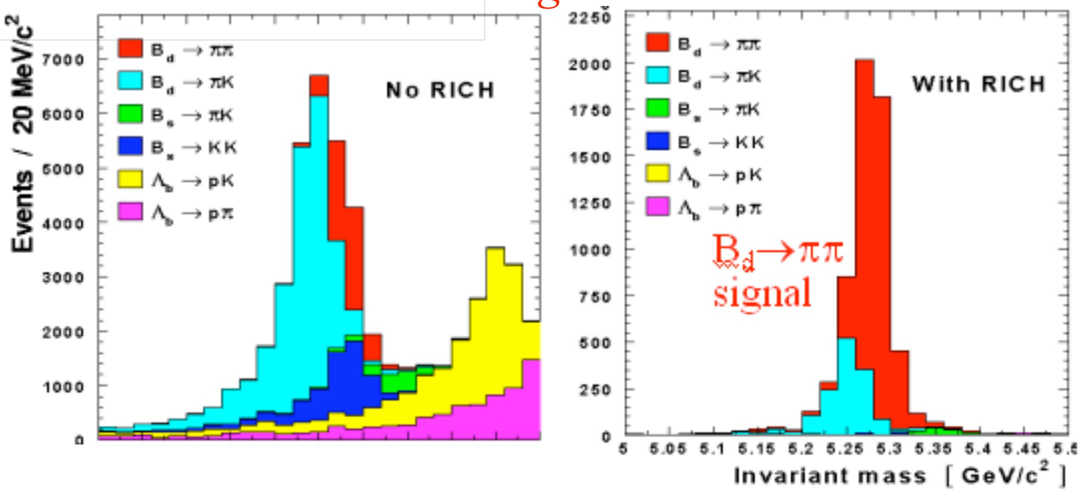
<ε(K→K,p)> = 83%

<ε(π→K,p)> = 6%

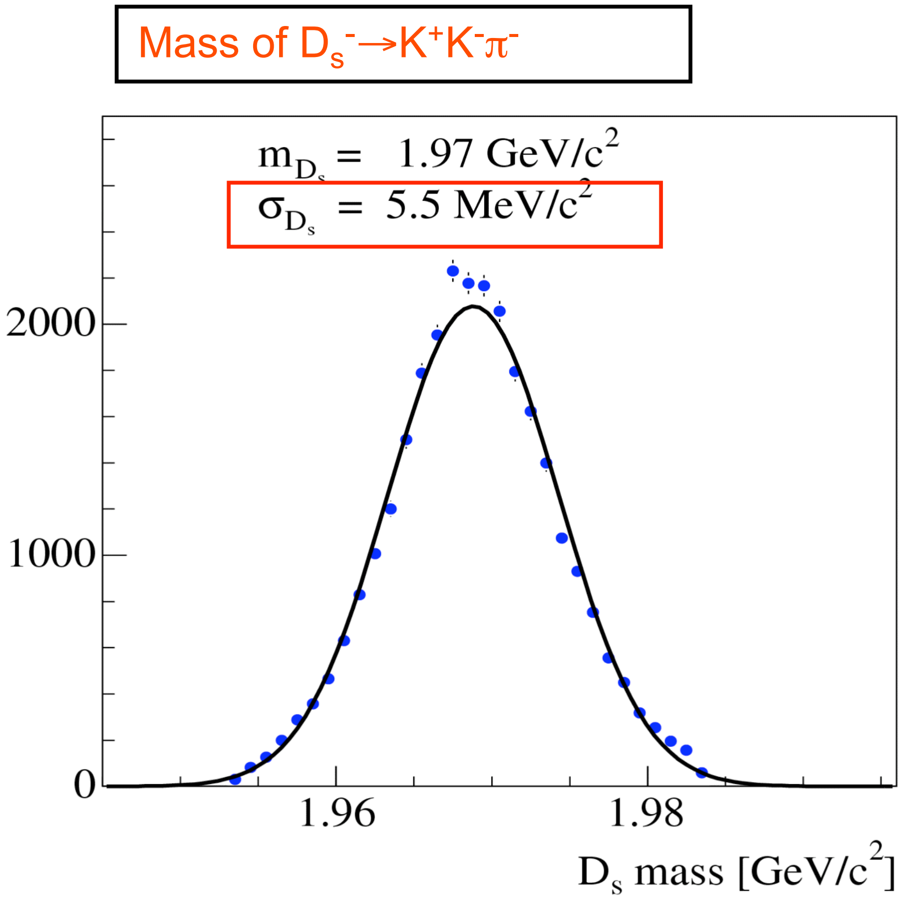
Clean separation of two-body B decays, e. g. B→ ππ

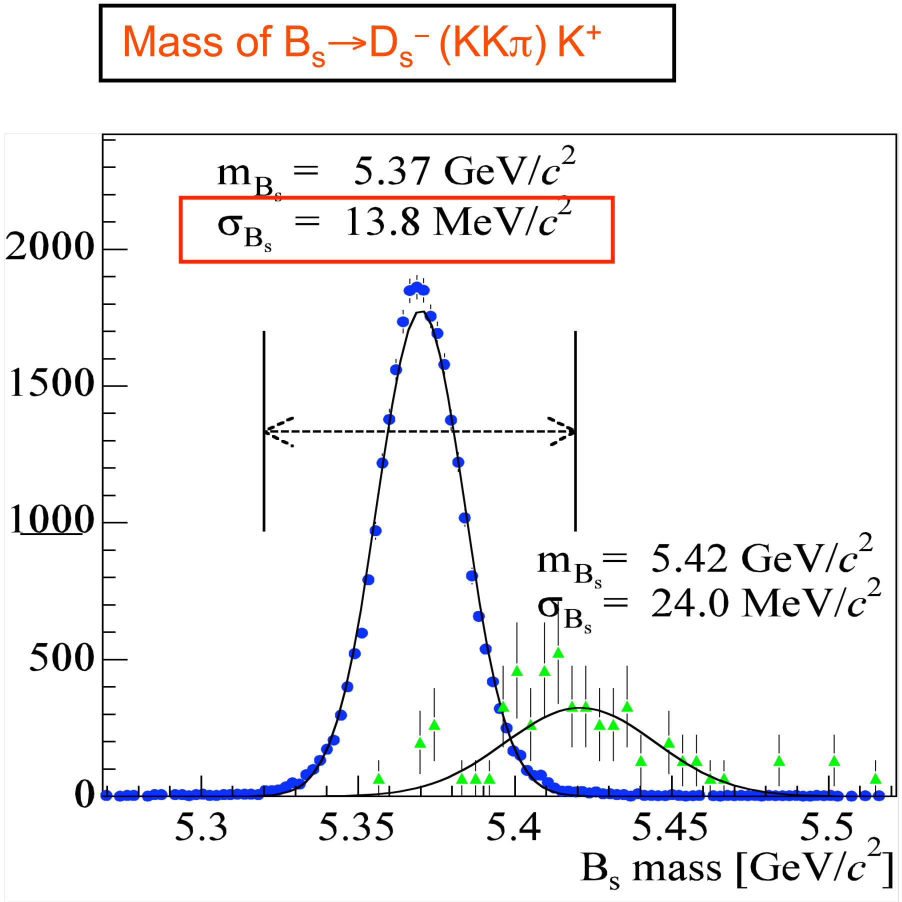
Lepton ID:
μ efficiency:94%
e efficiency:78%
π mis-id rate:1%

Details of particle identification: see C.Jones' talk

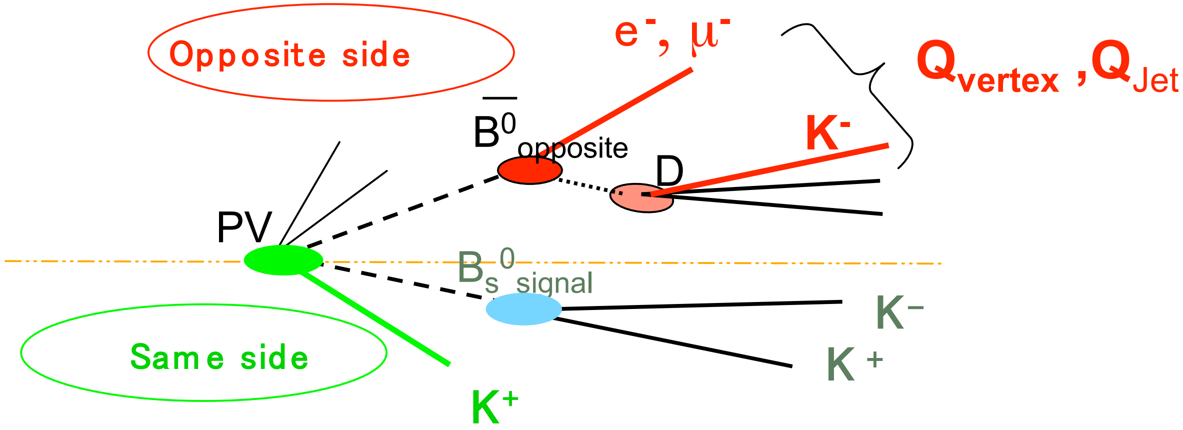


Mass resolution





Flavour tagging



Tag	$\varepsilon D^2 = \varepsilon(1-2w)^2$
Opposite μ	0.7%–1.8%
Opposite e	0.4%–0.6%
Opposite K	1.6%–2.4%
Opposite Q_{vtx}	0.9%–1.3%
Same side π (B^0)	0.8%–1.0%
Same side K (B_s)	2.7%–3.3%
Combined (B^0)	4%–5%
Combined (B_s)	7%–9%

Opposite side:

- *High-Pt leptons*
- *$K^\pm$ from $b \to c \to s$*
- *Vertex charge*
- *Jet charge*

Same side:

- *Fragmentation $K^\pm$ accompanying B_s*
- *$\pi^\pm$ from $B^{**} \to B^{(*)} \pi^\pm$*

Figure of merit:

$\varepsilon D^2 = \varepsilon(1-2\omega)^2$: tagging power in %

ε: tagging efficiency;

ω: wrong tagging fraction

$\leftarrow$ *Obtained from fully simulated signal events passing trigger and selection*

LHCb Physics programme

- B_s ***oscillation frequency, phase and*** $\Delta\Gamma_s$
  - $B_s \rightarrow D_s\pi$, $J/\Psi\Phi$, $J/\Psi\eta$, $\eta_c\Phi$
- α ***from*** $B_d \rightarrow \pi^0\pi^-\pi^+$
- β ***with*** $B_d \rightarrow J/\psi K_S$ ***as a proof of principle***
  - *And* β *from* $b \rightarrow s$ *penguin*
- γ ***in various channels, differing sensitivity to new physics:***
  - *Time-dependent CP asymmetry of* $B_s \rightarrow D_s^- K^+$ *and* $D_s^+ K^-$
  - *Time dependent CP asymmetries of* $B_d \rightarrow \pi^+\pi^-$ *and* $B_s \rightarrow K^+K^-$
  - *Comparison of decay rates in the* $B_d \rightarrow D^0 K^{*0}$ *system*
  - *Comparison of decay rates in the* $B^- \rightarrow D^0 K^-$ *system*
  - *Dalitz analysis of* $B^- \rightarrow D^0 K^-$ *and* $B_d \rightarrow D^0 K^{*0}$
- ***Rare decays***
  - *Radiative penguin* $B_d \rightarrow K^* \gamma$, $B_s \rightarrow \Phi\gamma$, $B_d \rightarrow \omega\gamma$
  - *Electroweak penguin* $B_d \rightarrow K^{*0} \mu^+\mu^-$
  - *Gluonic penguin* $B_s \rightarrow \Phi\Phi$, $B_d \rightarrow \Phi K_s$
  - *Rare box diagram* $B_s \rightarrow \mu^+\mu^-$
- B_c , **b*-baryon physics + unexpected !***

Sensitivity studies

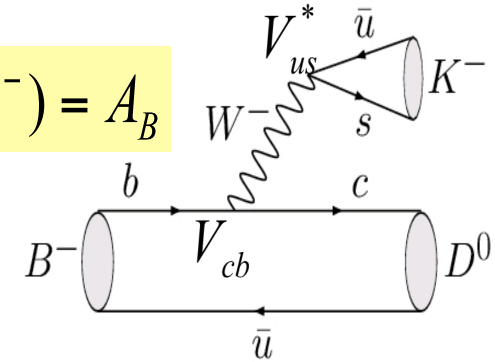
- *For all the sensitivity studies, we use toy MC with detector resolutions extracted from a full Geant simulation of the events*

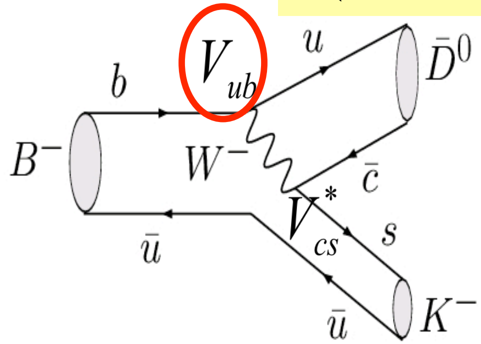
- *Annual yields estimated with full simulated Geant events*

- *Sample of 40 million fully simulated and reconstructed b-inclusive decays are used for the B/S estimates*

$B^{\pm} \rightarrow D^0 K^{\pm}$

$A(B^- \rightarrow D^0 K^-) = A_B$





$A(B^- \rightarrow \overline{D}^0 K^-) = A_B r_B e^{i(\delta-\gamma)}$

No need for a time-dependent analysis

γ can be extracted from the interference of these two processes in charged $B \rightarrow D^0 K$ decays with D^0/D^0 decaying to a common final state

- *r_B is the relative colour and CKM suppression between the two modes O(0.1) – dilutes sensitivity to γ*
- *δ is the strong phase difference - invariant under CP*

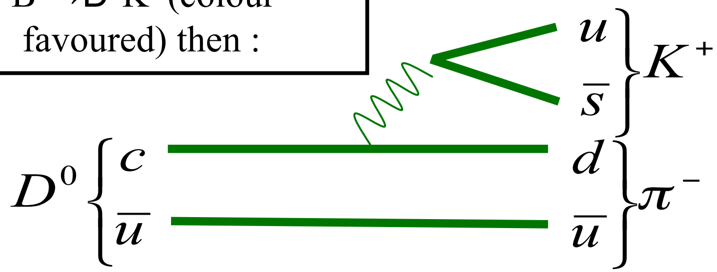
- *Two types of D^0 decays under study:*

Cabibbo favoured self-conjugate decays e.g. $K_s\pi\pi$ - sensitivity under study

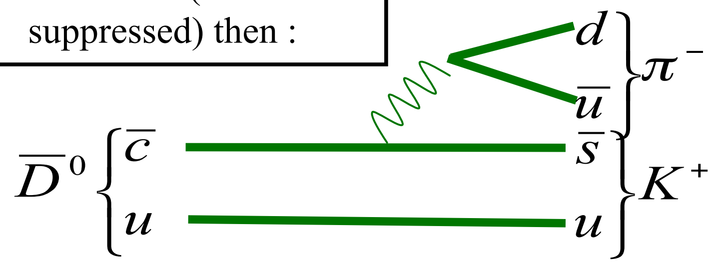
Cabibbo favoured/doubly Cabibbo suppressed modes e.g. $K\pi, K\pi\pi\pi$

γ from $B^{\pm} \rightarrow D^0K^{\pm}$, ADS method

$B^- \rightarrow D^0K^-$ (colour favoured) then :



$B^- \rightarrow \overline{D}^0K^-$ (colour suppressed) then :



Reversed suppression of D decays versus B decays results in similar amplitudes,
So big interference effect

Measure relative rates (no need for tagging or time asymmetry)

With $r_B = 0.15$:
Cabibbo favoured: ~60K events for $2fb^{-1}$
Cabibbo suppressed: ~2K events for $2fb^{-1}$
50 times more than b-factories

Suppressed rates have O(1) interference effects since $r_B \sim r_D$
Particularly sensitive to γ

Rates depend on 5 parameters: γ, r_B, δ_B,
$r_D^{K\pi}$ (magnitude of the ratio between two D decays)
$\delta_D^{K\pi}$ (CP conserving strong phase difference)

γ from $B^\pm \rightarrow D^0K^\pm$

Relative rates more unknown than equations
Use other decays e.g. $K\pi\pi\pi$ or $KK,\pi\pi$

Inputs: γ=60°, δ_B=130°, r_B=0.15

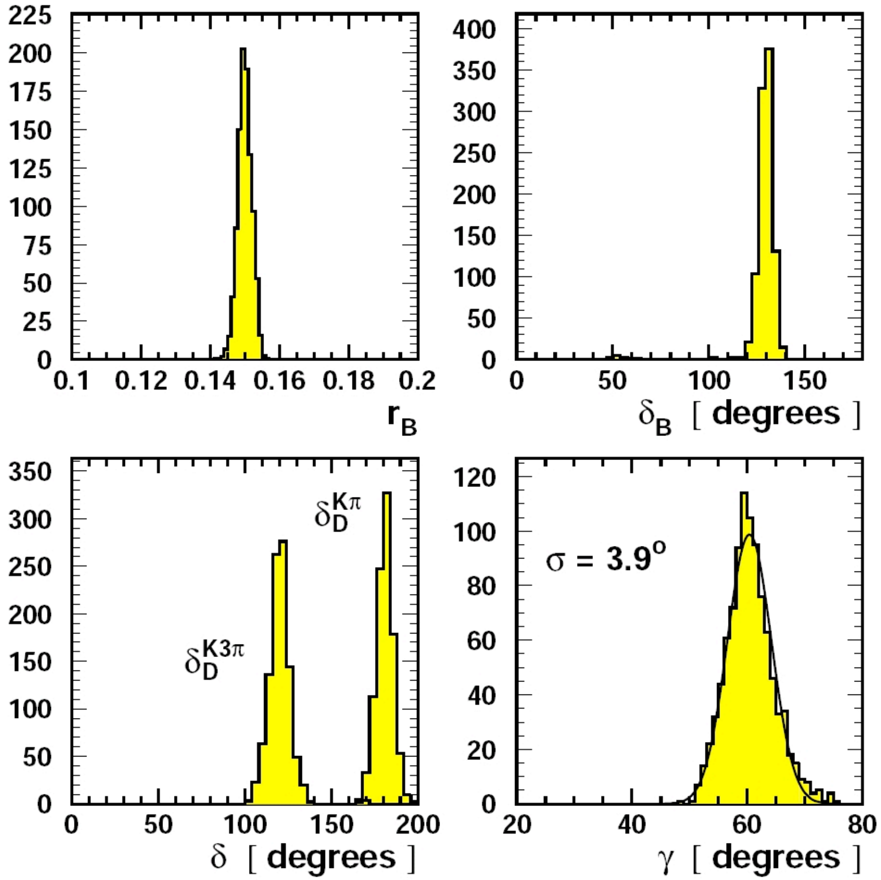
Fit for r_B, δ_B, $\delta_D^{K\pi}$, $\delta_D^{K3\pi}$, γ

No background: $\sigma(\gamma)$~3.9°

Adding background:

		B/S πK, KK, $\pi\pi$ 0	1	2	5
	0	3.9°	4.0°	4.0°	4.1°
B/S	1	4.6°	4.8°	4.8°	5.0°
$K\pi\pi\pi$	2	5.0°	5.1°	5.3°	5.5°
	5	5.6°	5.9°	6.0°	6.3°

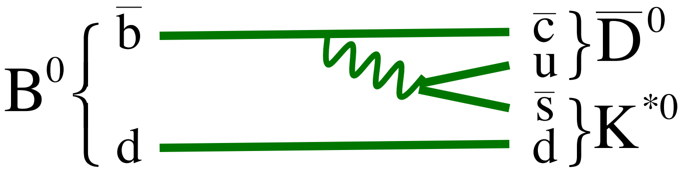
With background: $\sigma(\gamma)$~5°

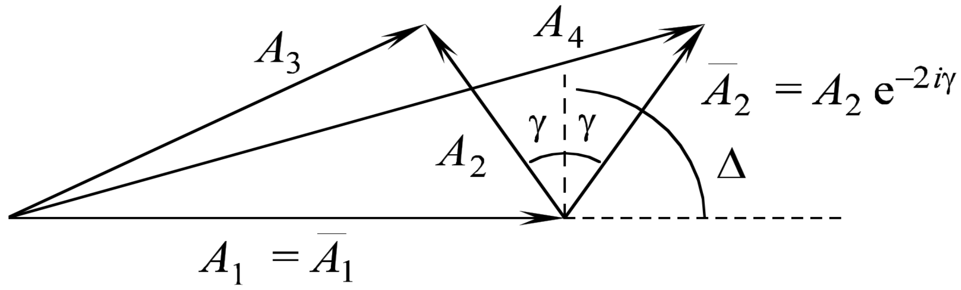


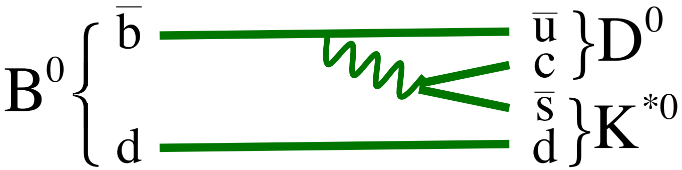
With latest r_B =0.077 value we expect sensitivity to decrease
No background: $\sigma(\gamma)$~4.1°, effect with background under study

GLW method - γ from $B^0 \to D^0K^{*0}$

- *Dunietz variant of Gronau-Wyler method makes use of interference between two colour-suppressed diagrams interfering via D^0 mixing :*







$A_1 = A(B^0 \to \bar{D}^0K^{*0})$: $b \to c$ transition, phase 0

$A_2 = A(B^0 \to D^0K^{*0})$: $b \to u$ transition, phase $\Delta+\gamma$

$A_3 = \sqrt{2}\,A(B^0 \to D_{CP}K^{*0}) = A_1+A_2$, because $D_{CP}=(D^0+\bar{D}^0)/\sqrt{2}$

- *Measuring the 6 decay rates $B^0 \to D^0(K\pi,\pi K,KK)K^{*0}$ + CP conjugates allows γ to be extracted without flavour tagging or proper time determination*

GLW method - γ from $B^0 \rightarrow D^0 K^{*0}$

- *LHCb expectations for 2 fb^{-1} (γ=65°, Δ=0) :*

Mode (+ cc)	Yield	S/B_{bb} (90%CL)
$B^0 \rightarrow D^0\ (K^+\pi^-)\ K^{*0}$	3.4k	> 2
$B^0 \rightarrow D^0\ (K^-\pi^+)\ K^{*0}$	0.5k	> 0.3
$B^0 \rightarrow D^0_{CP}\ (K^+K^-)\ K^{*0}$	0.6k	> 0.3

$\rightarrow \sigma(\gamma) \sim 8°$ *in one year*

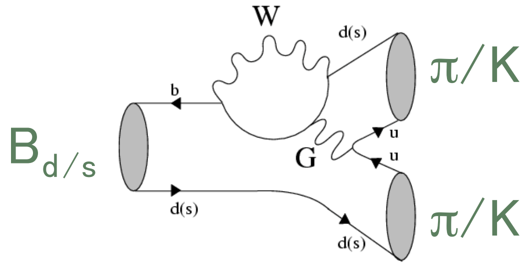
- *Work ongoing to understand biases introduced by DCS amplitude in D->Kπ*

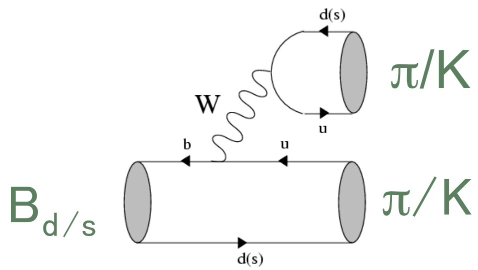
γ from $B \rightarrow KK, \pi\pi$

- Measure time dependant asymmetries for $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ to determine A_{dir} and A_{mix}

$$A_{CP}(t) = A_{dir} \cos(\Delta m\ t) + A_{mix} \sin(\Delta m\ t)$$

- A_{dir} and A_{mix} depend on
  - γ
  - Mixing phases ϕ_d or ϕ_s
  - Penguin/Tree ratio $= de^{i\theta}$
- ϕ_d and ϕ_s from $J/\psi\phi$ and $J/\psi Ks$
- U-spin symmetry: $d_{\pi\pi}=d_{KK}$, $\theta_{\pi\pi}=\theta_{KK}$
- 4 observables, 3 unknowns: solve for γ





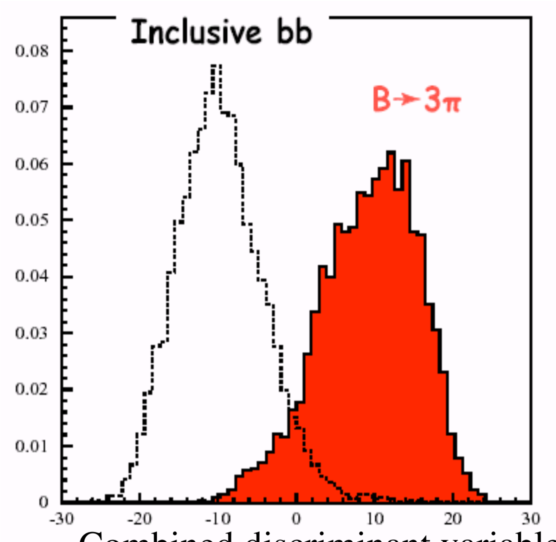
26K $B_d \rightarrow \pi\pi$ /year, B/S<0.7

37K $B_d \rightarrow KK$ /year, B/S<0.3

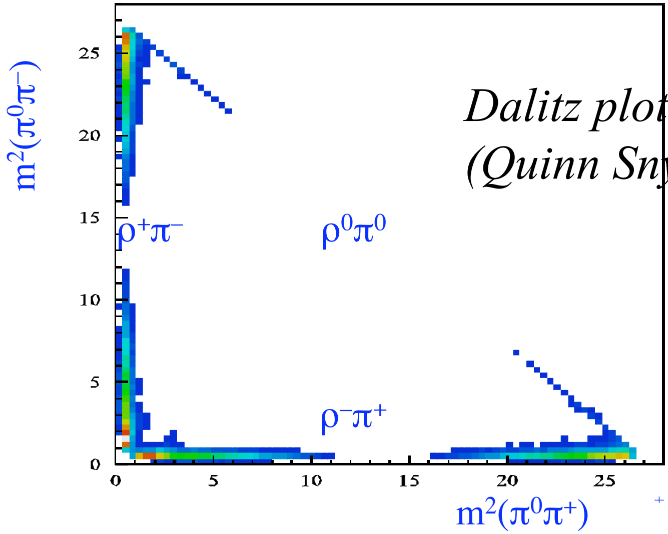
$\boxed{\sigma(\gamma) \sim 5°}$

Angle α from $B_d \to \pi^0 \pi^+ \pi^-$

- *Selection based on multivariate analysis*
- *Use resolved and merged π^0*
- *Expect 14k events per year, B/S < 1*

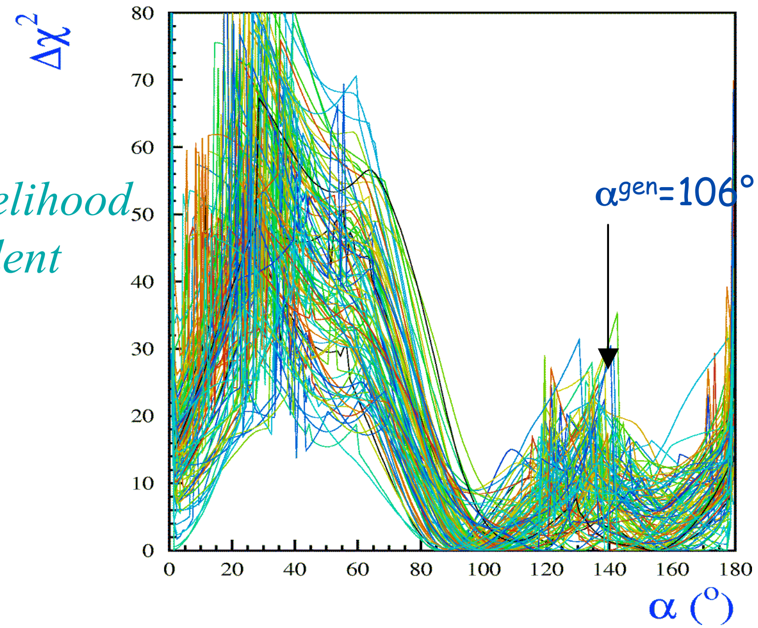


Combined discriminant variable



Dalitz plot analysis (Quinn Snyder method)

11-parameter likelihood fit to time-dependent Dalitz plot:



$\sigma(\alpha)$~10° with 2 fb^{-1}

B_s mixing: Δm_s

$$CDF: \Delta m_s = 17.33^{+0.42}_{-0.21} \pm 0.07 \quad ps^{-1}$$

$$D0: 17 < \Delta m_s < 21\ ps^{-1} \quad @90\%\ c.l.$$

LHCb:
Measured using $B_s \to D_s^- \pi+$
80k events in one year,
B/S<0.3

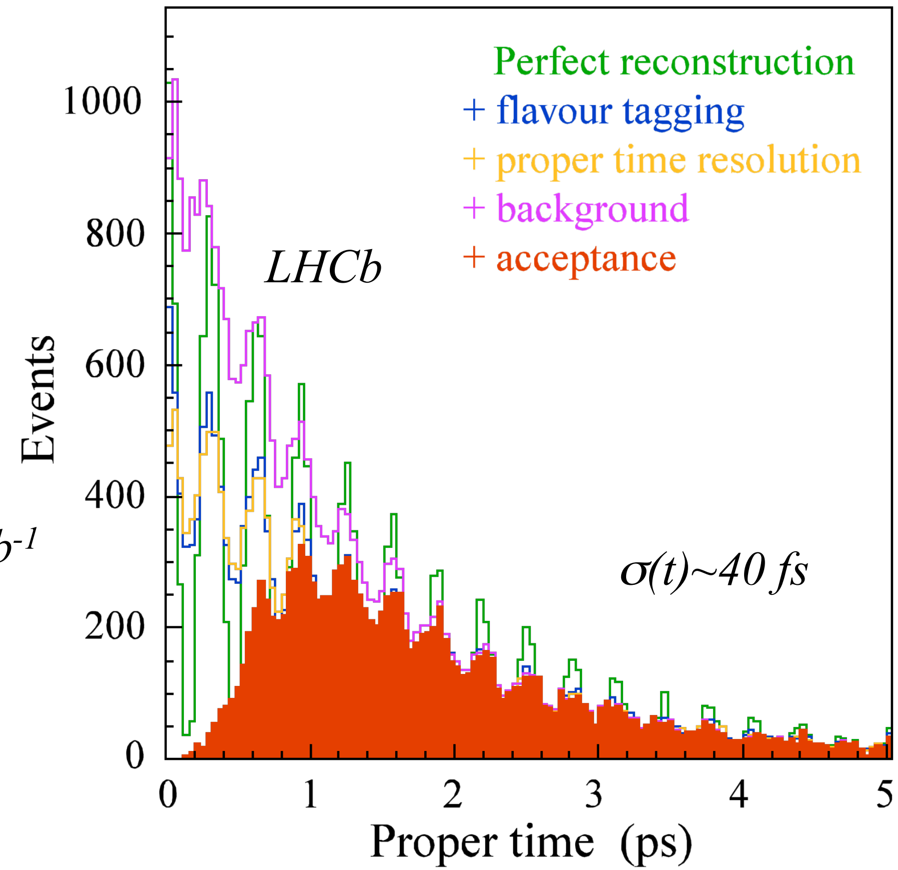
Given the low value of Δm_s, LHCb will be able to measure it with much less than $2fb^{-1}$

High precision expected in one year:

$\boxed{\sigma_{stat}(\Delta m_s) \sim 0.01\ ps^{-1}}$

$B_s \to D_s^- \pi^+$

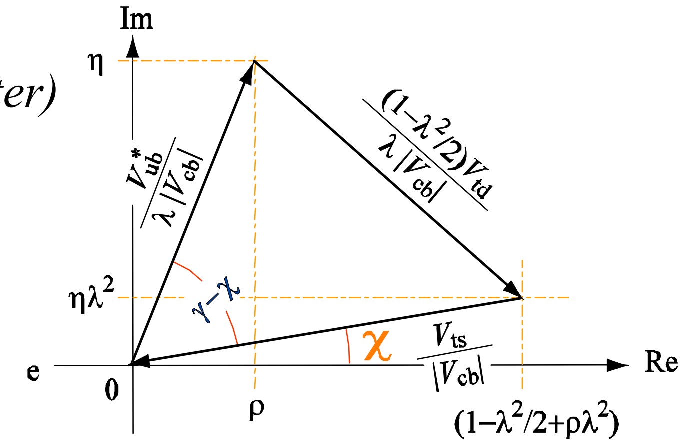
Distribution of unmixed sample after 1 year (2 fb^{-1}) for Δm_s= 20 ps^{-1}



Very good resolution for oscillations: time-dependent analyses with B_s decays, B_s mixing phase, CP violation in the mixing…

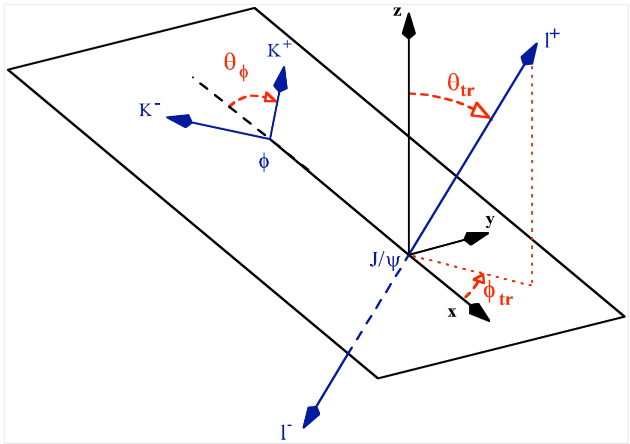
B_s mixing phase

ϕ_s is very small in SM: $\phi_s = -2\chi = -0.036 \pm 0.003$ (CKM fitter)
Sensitive probe of new physics



Use $B_s \rightarrow J/\Psi\phi$ (~120k events/year expected, S/B>3)
Final state contains CP-even and CP-odd contributions

Angular analysis to separate
CP even and CP odd

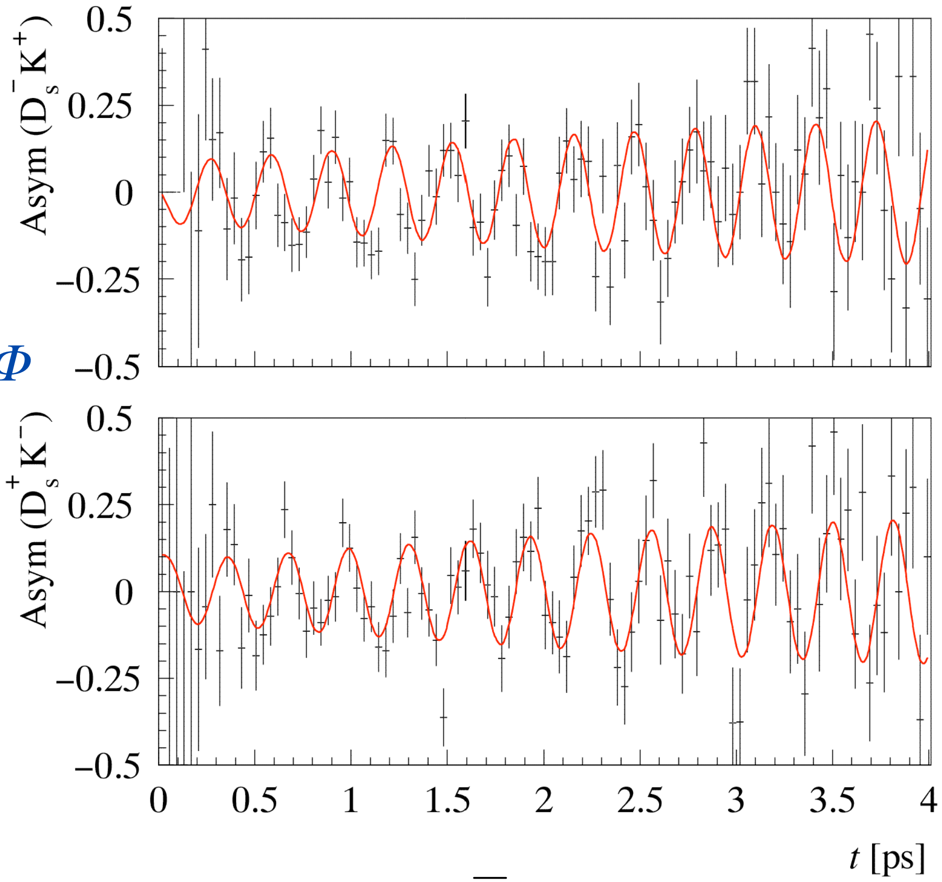


$\sigma(\sin\phi_s)$~0.03 and $\sigma(\Delta\Gamma_s/\Gamma_s)$~0.02
(with Δm_s = 20 ps^{-1}) in 1 year

Pure CP modes $B \rightarrow J/\Psi\eta$ ($\gamma\gamma, \pi^+\pi^-\pi^0$), $\eta_c\phi$ added:
$\sigma(\sin\phi_s)$ ~ 0.013 in 5 years

Angle γ from $B_s \rightarrow D_s K$

- *Interference between 2 tree diagrams*
  - *insensitive to NP in Bs mixing*
- *Measure $\gamma + \phi_s$ from time-dependent rates of $B_s \rightarrow D_s^+ K^-$ and $B_s \rightarrow D_s^- K^+$ +cc*
  - *Mistag from $B_s \rightarrow D_s \pi$*
  - *Subtract ϕ_s measured with $B \rightarrow J/\Psi\Phi$*



B_s-$\overline{B_s}$ asymmetries after 5 years of data

With 2 fb^{-1}, $\Delta m_s = 20\ ps^{-1}$, $\Delta\Gamma_s/\Gamma_s = 0.1$, $55° < \gamma < 105°$:

$\boxed{\sigma(\gamma) \sim 14°}$

A_{FB} in $B_d \rightarrow K^{*0}\ \mu^+\ \mu^-$

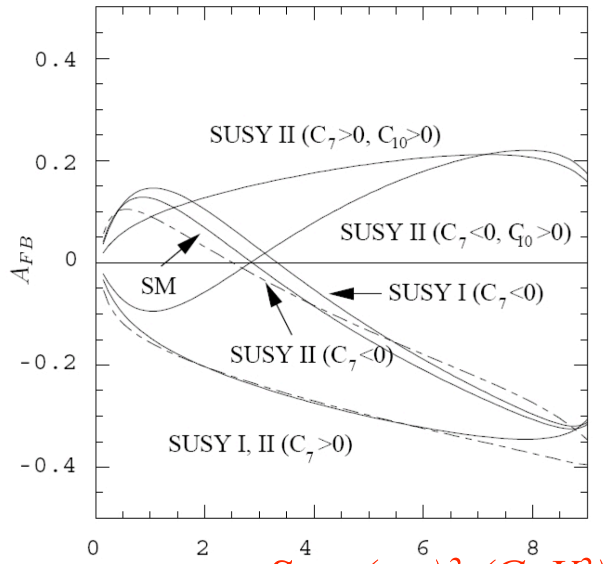
Forward-backward asymmetry A_{FB} in the $\mu\mu$ rest-frame is sensitive to NP

SM branching ratio ~ 10^{-6}

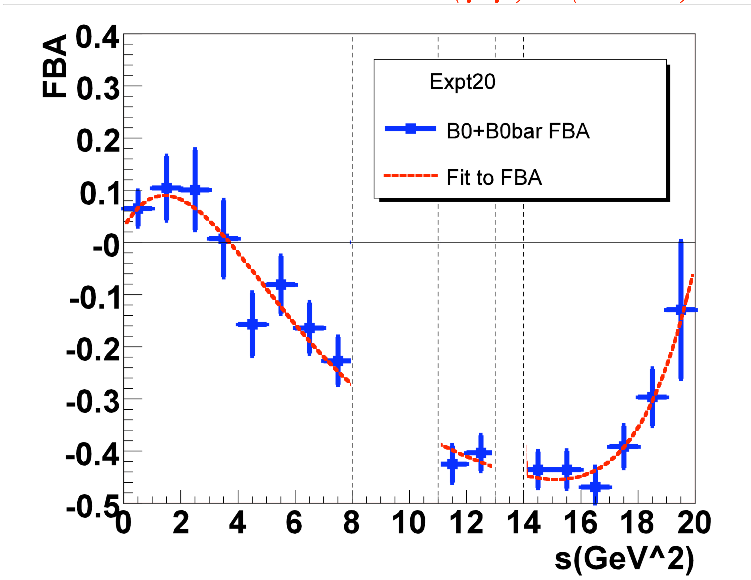
~4400 $B_d \rightarrow K^{*0}\ \mu^+\ \mu^-$ events/year
B/S< 2.6

Further optimisation under way
Signal yield improvement

With $10fb^{-1}$:
zero of $A_{FB}(s)$ located to $\boxed{\pm 0.53\ GeV^2}$



$S=m(\mu\mu)^2\ (GeV^2)$



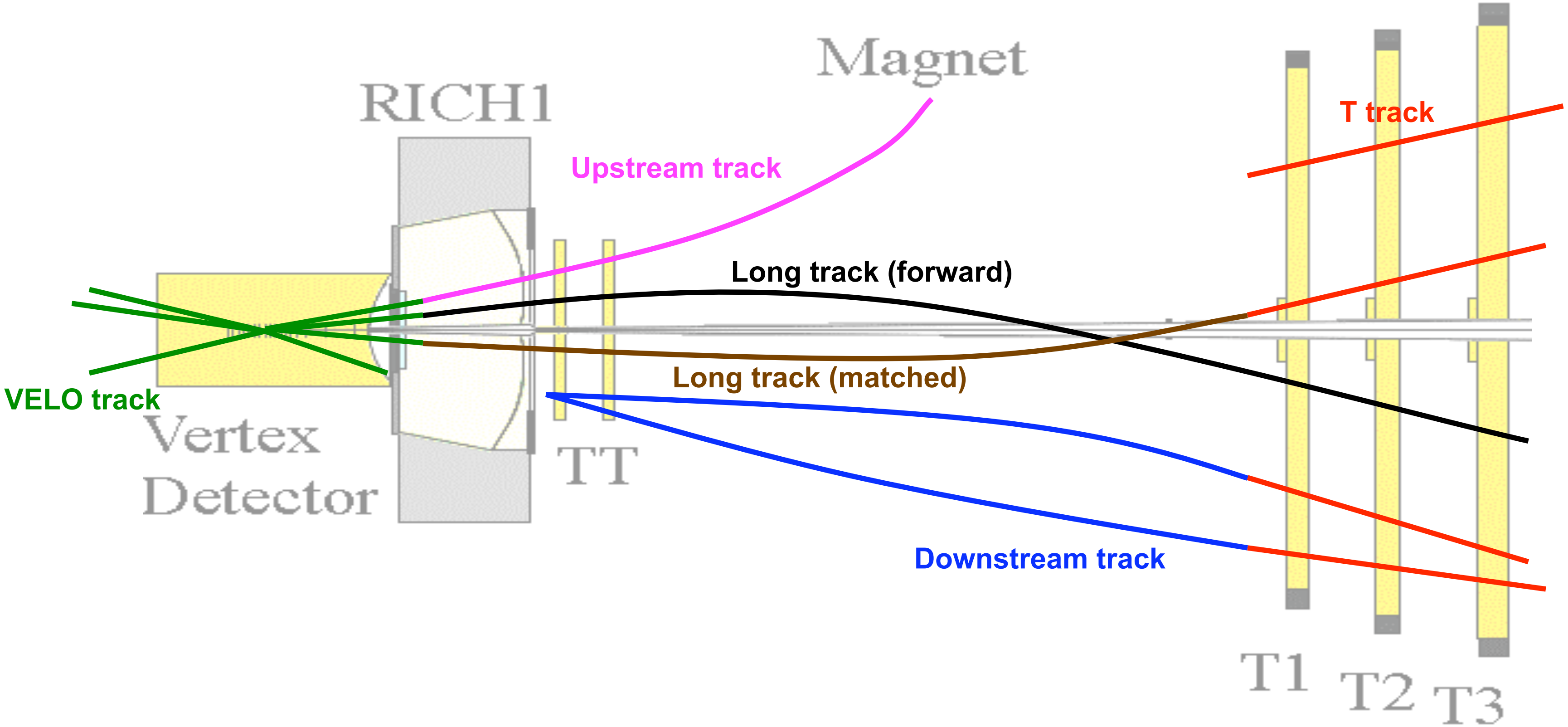
Conclusions

- *LHCb will have excellent statistics for B decays, including B_s, B_c and b-baryons*
- *Large B_s sample in flavour specific and CP-eigenstates modes: unprecedented investigation of all B_s mixing parameter*
  $\rightarrow$ *constrain/discover new physics*
- *Many measurements of CP asymmetry and rare decays*
  - $\sigma(\alpha) \sim 10°$
  - $\sigma(\phi_s) \sim 2°$
  - $\sigma(\gamma) \sim 5°$
- *CP angles determined via channels with different sensitivity to new physics*

- *LHCb offers an excellent opportunity to spot new physics beyond Standard Model and will be ready in 2007*

Spares

Tracking

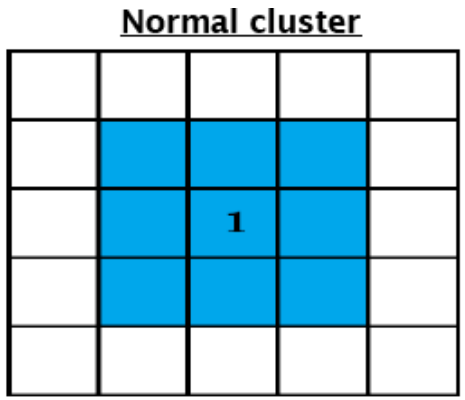


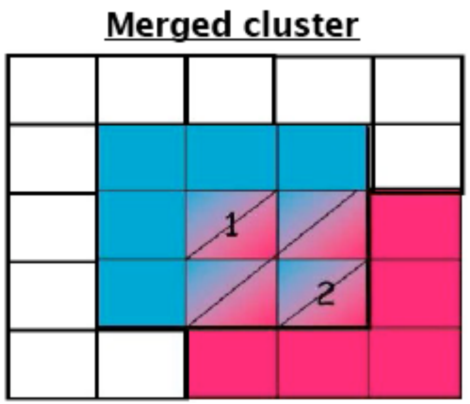
Long tracks	⇒	highest quality for physics
Downstream tracks	⇒	needed for efficient K_S finding
Upstream tracks	⇒	lower p, worse p resolution, useful for RICH1 pattern recognition

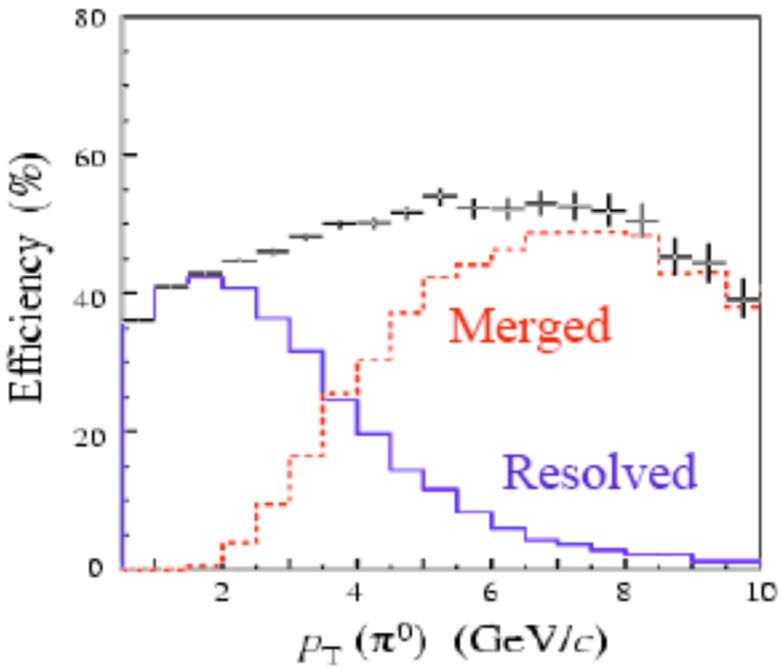
Details on tracking: C.Jones' talk

Neutral reconstruction

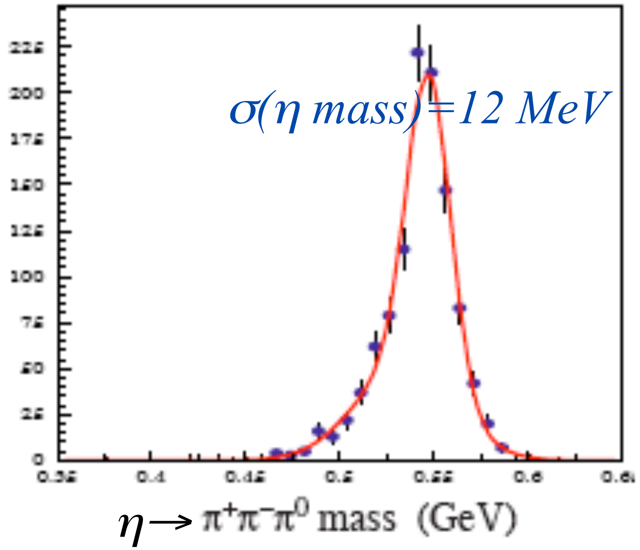
Good efficiency for π^0 in $B^0 \rightarrow \pi^+ \pi^- \pi^0$, using both *resolved (separate clusters) and merged cluster shapes in the calorimeter (unassociated to charged tracks)*







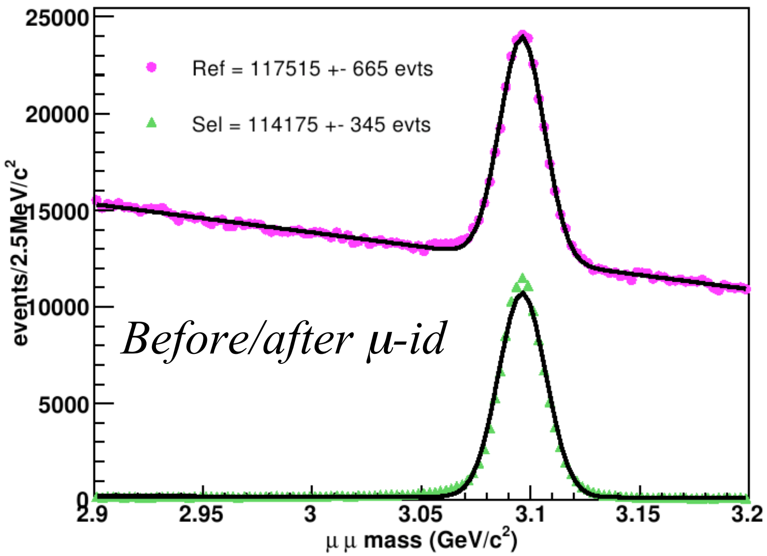
Reconstruction efficiency ~53%



Particle identification: leptons

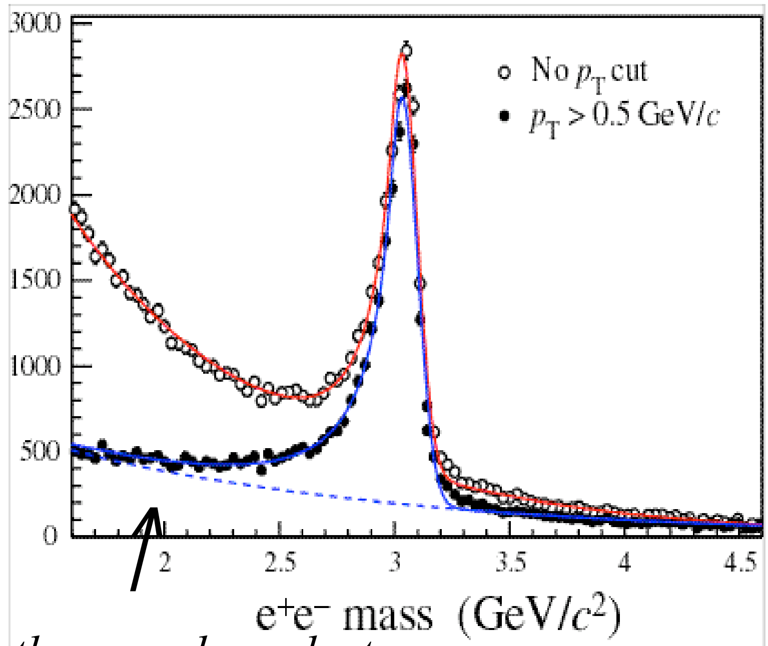
μ Efficiency = 94%

π mis-ID rate 1.0%



Electron Efficiency = 78%

π mis-ID rate 1.0%

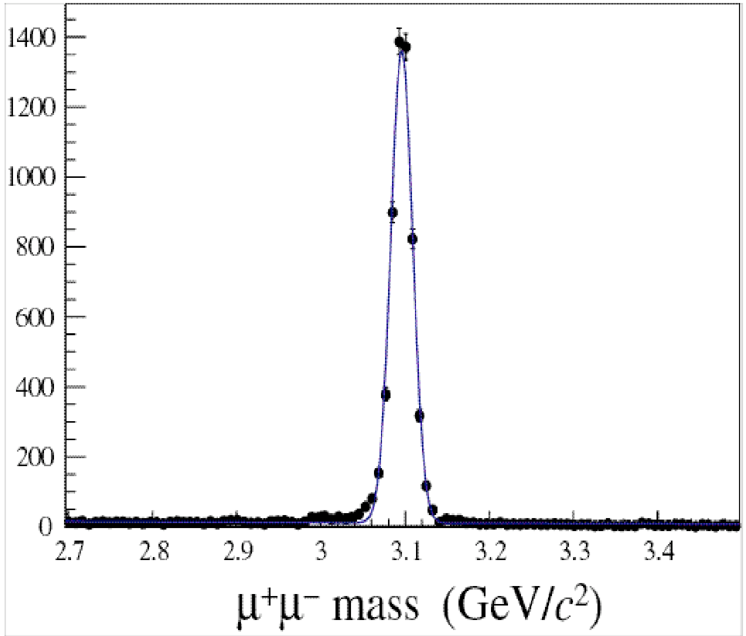


Electron background: mostly secondary electrons and ghosts, rejected by PT cut

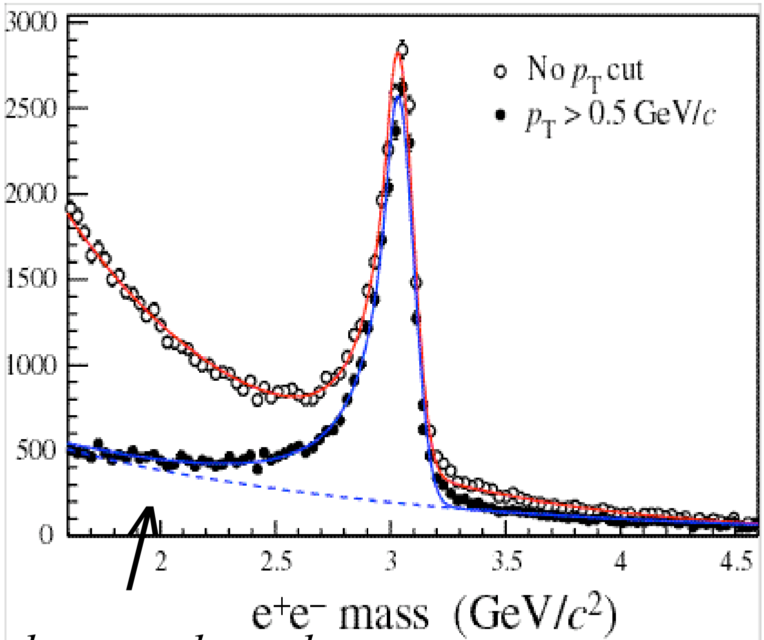
Lepton ID: ECAL, Muon chambers
See C.Jones' talk

Particle identification: leptons

μ Efficiency = 94%
π mis-ID rate 1.0%



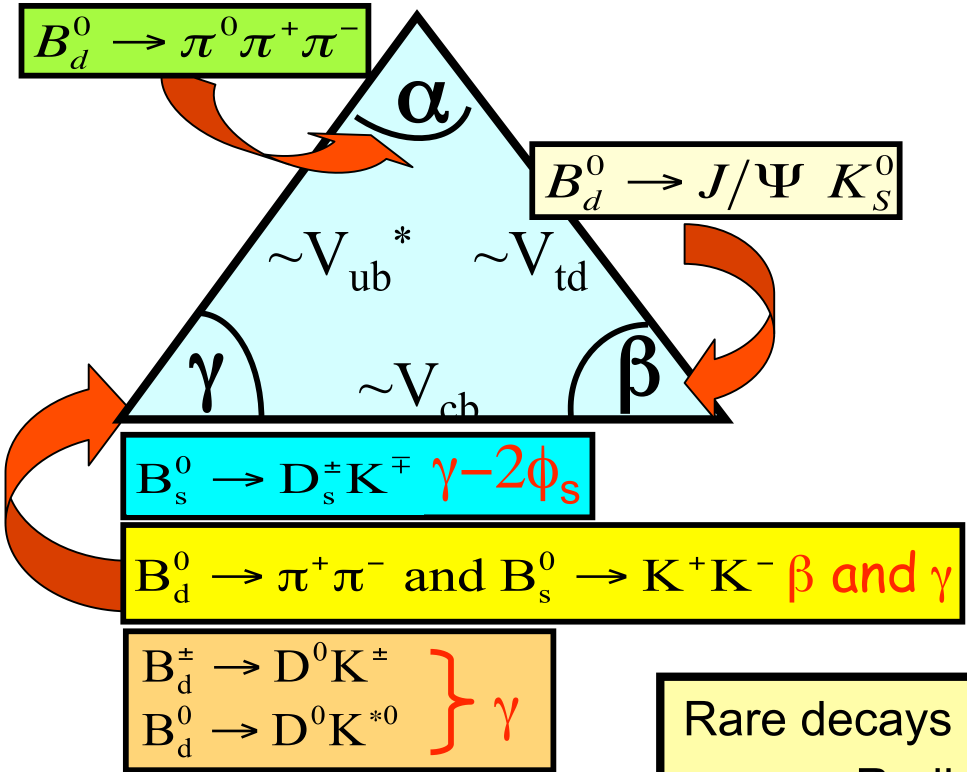
Electron Efficiency = 78%
π mis-ID rate 1.0%

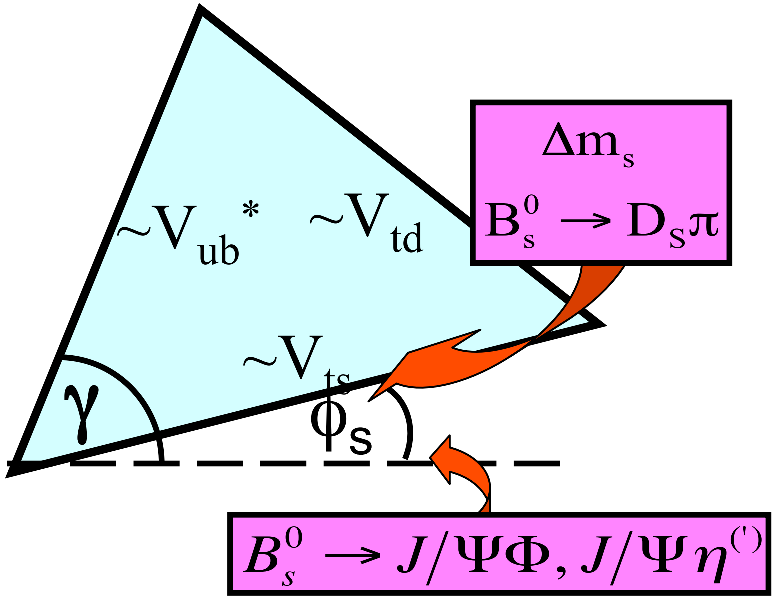


Electron background: mostly secondary electrons and ghosts, rejected by PT cut

Lepton ID: ECAL, Muon chambers
See C.Jones' talk

LHCb Physics programme





B production ,
B_c , b-baryon physics

Rare decays

- Radiative penguin e.g. $B_d \to K^* \gamma$, $B_s \to \Phi\gamma$
- Electroweak penguin e.g. $B_d \to K^{*0} \mu^+\mu^-$
- Gluonic penguin e.g. $B_s \to \Phi\Phi$, $B_d \to \Phi K_s$
- Rare box diagram e.g. $B_s \to \mu^+\mu^-$

γ from $B \to DK$, ADS method

Rates depend on 5 parameters: g, rB, dD
rDkp (magnitude of the ratio between two D decays)
dDKp (CP conserving strong phase difference)

$$\Gamma(\mathrm{B}^- \to (\mathrm{K}^-\pi^+)_\mathrm{D}\,\mathrm{K}^-) \;\propto\; 1 + (r_B\, r_D^{\mathrm{K}\pi})^2 + 2\, r_B r_D^{\mathrm{K}\pi} \cos\left(\delta_B - \delta_D^{\mathrm{K}\pi} - \gamma\right) \qquad (1) \quad \sim 30\mathrm{k}$$

$$\Gamma(\mathrm{B}^- \to (\mathrm{K}^+\pi^-)_\mathrm{D}\,\mathrm{K}^-) \;\propto\; r_B^2 + (r_D^{\mathrm{K}\pi})^2 + 2\, r_B r_D^{\mathrm{K}\pi} \cos\left(\delta_B + \delta_D^{\mathrm{K}\pi} - \gamma\right) \qquad (2) \quad \sim 1\mathrm{k}$$

$$\Gamma(\mathrm{B}^+ \to (\mathrm{K}^+\pi^-)_\mathrm{D}\,\mathrm{K}^+) \;\propto\; 1 + (r_B\, r_D^{\mathrm{K}\pi})^2 + 2\, r_B r_D^{\mathrm{K}\pi} \cos\left(\delta_B - \delta_D^{\mathrm{K}\pi} + \gamma\right) \qquad (3) \quad \sim 30\mathrm{k}$$

$$\Gamma(\mathrm{B}^+ \to (\mathrm{K}^-\pi^+)_\mathrm{D}\,\mathrm{K}^+) \;\propto\; r_B^2 + (r_D^{\mathrm{K}\pi})^2 + 2\, r_B r_D^{\mathrm{K}\pi} \cos\left(\delta_B + \delta_D^{\mathrm{K}\pi} + \gamma\right) \qquad (4) \quad \sim 1\mathrm{k}$$

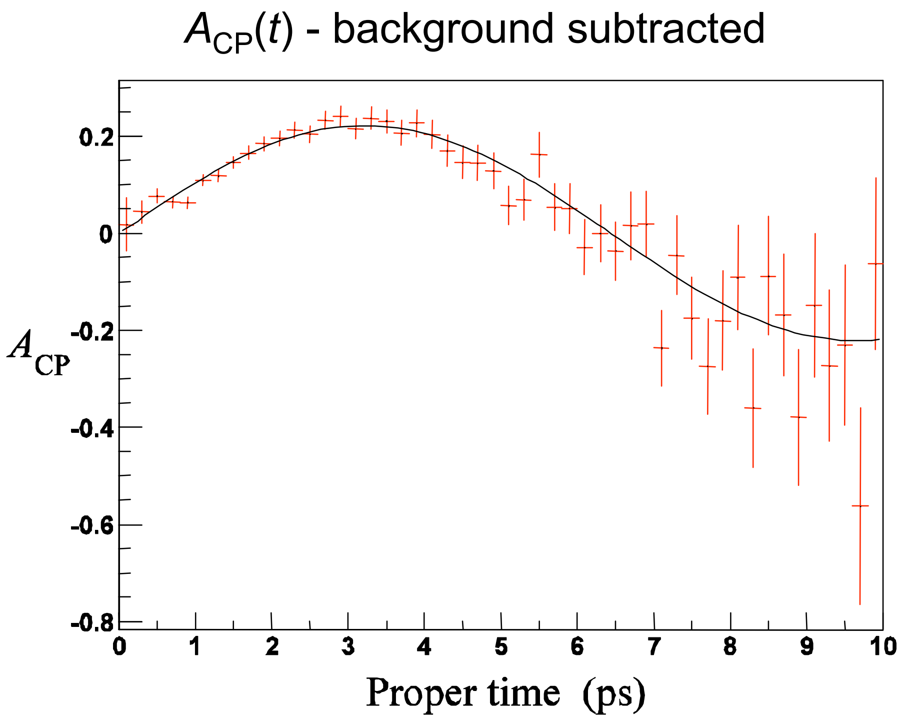
For 2 fb-1 50 times more than
B-factories

Suppressed rates (2) and (4) have O(1) interference effects since rB~rD
so particularly sensitive to g

Relative rates more unknown than equations
Use other decays e.g. Kppp or KK,pp

sin 2β with $B^0 \rightarrow J/\psi K_S$

Very well measured at B-factories
In LHCb will be important check of
CPV analyses and tagging performances



~240K $B^0 \rightarrow J/\Psi K_s$ events/year

σ_{stat}(sin 2β)~0.02
in one year of data taking

B_s mixing: Δm_s

$CDF: \Delta m_s = 17.33^{+0.42}_{-0.21} \pm 0.07 \quad ps^{-1}$

$D0: 17 < \Delta m_s < 21\ ps^{-1} \quad @90\%\ c.l.$

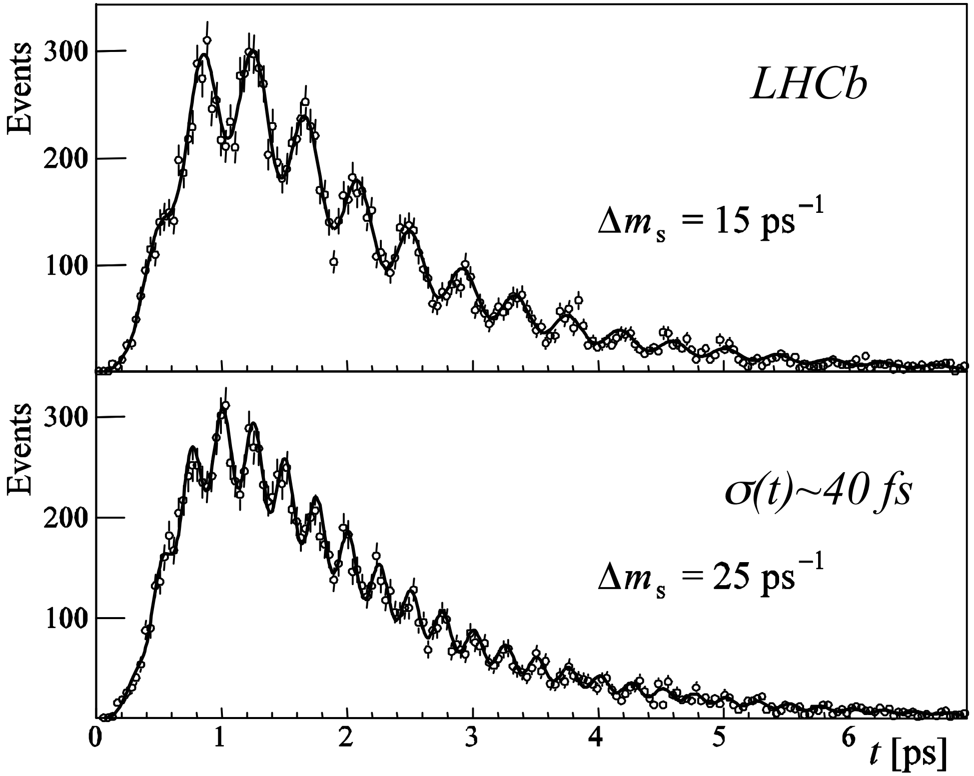
LHCb:
Measured using $B_s \to D_s^- \pi+$
80K events in one year,
B/S<0.3

High precision expected in one year:

$\boxed{\sigma_{stat}(\Delta m_s) \sim 0.01\ ps^{-1}}$

$B_s \to D_s^- \pi^+$

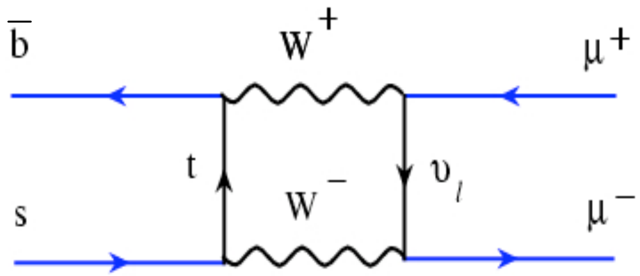
Distribution of unmixed sample after 1 year (2 fb^{-1})

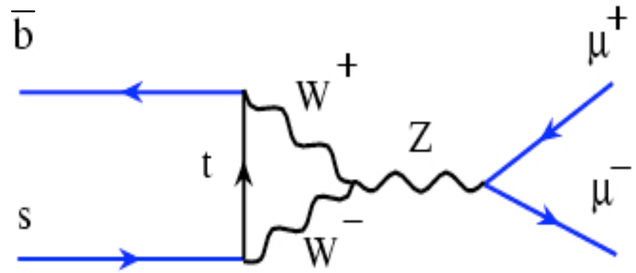


Very good resolution for oscillations, so we can measure CP asymmetry in Bs system

$B_s \rightarrow \mu^+\mu^-$

Branching ratio ~ 3.5 x 10-9 in SM
Sensitive to new physics, can be strongly enhanced by SUSY





LHCb aims for 2σ measurement in 2 years
Difficult to get reliable estimate of expected background

LHCb performance with $2fb^{-1}$ (1 year)

	Channel	Yield*	B_{bb}/S	Precision
γ	$B_s \to D_s K$	5.4k	<1	$\sigma(\gamma) \approx 14^\circ$
	$B_d \to \pi\pi$	26k	<0.7	
	$B_s \to KK$	37k	0.3	$\sigma(\gamma) \approx 6^\circ$
	$B_d \to D^0(K^-\pi^+)K^{*0}$	0.5k	<0.3	
	$B_d \to D^0(K^+\pi^-)K^{*0}$	2.4k	<2	$\sigma(\gamma) \approx 8^\circ$
	$B_d \to D_{CP}(K^+K^-)K^{*0}$	0.6k	<0.3	
	$B^- \to D^0(K^-\pi^+)K^-$	60k	0.5	
	$B^- \to D^0(K^+\pi^-)K^-$	2k	0.5	$\sigma(\gamma) \approx 5^\circ$
α	$B_d \to \pi^0\pi^-\pi^+$	14k	0.8	$\sigma(\alpha) \approx 10^\circ$
ϕ_s	$B_s \to J/\Psi\Phi$	125k	0.3	$\sigma(\phi_s) \approx 2^\circ$
	$B_s \to J/\Psi\eta$	12k	2-3	
	$B_s \to \eta_c\Phi$	3k	0.7	
Δm_s	$B_s \to D_s\pi$	80k	0.3	Δm_s up to 68 ps^{-1}
β	$B_d \to J/\Psi K_S$	216k	0.8	$\sigma(\sin 2\beta) \approx 0.022$
rare decays	$B_d \to K^*\mu^+\mu^-$	4.4k	<2.6	C_7^{eff}/C_9^{eff} with 13% error
	$B_s \to \mu^+\mu^-$	17	<5.7	NP search
	$B_d \to K^*\gamma$	35k	<0.7	$\sigma(A_{CP}^{dir}) \approx 0.01$

(*)Untagged annual yields after trigger, stat. only

B physics: LHC vs B factories

	$e^+e^- \rightarrow \Upsilon(4S) \rightarrow BB$ PEPII, KEKB	**pp→bbX** ($\sqrt{s}$ = 14 TeV, Δt_{bunch}=25 ns) LHCb	
Production σ_{bb}	1 nb	~500 μb	☺
Typical bb rate	10 Hz	100 kHz	
bb purity	~1/4	$\sigma_{bb}/\sigma_{inel}$ = 0.6% Trigger is a major issue !	☹
Pileup	0	0.5	
b-hadron types	B^+B^- (50%) B^0B^0 (50%)	B^+B^- (40%), B^0 (40%), B_s (10%) B_c (< 0.1%), b-baryons (10%)	☺
b-hadron boost	Small	Large (decay vertexes well separated)	
Production vertex	Not reconstructed	Reconstructed (many tracks)	
Neutral B mixing	Coherent B^0B^0 pair mixing	Incoherent B^0 and B_s mixing (extra flavour-tagging dilution)	☹
Event structure	BB pair alone	Many particles not associated with the two b hadrons	

Measuring γ : $B^+ \rightarrow D^0(K^0\pi^+\pi^-)K^+$

Giri, Grossman, Soffer, Zupan (PRD 68, 054018 (2003))

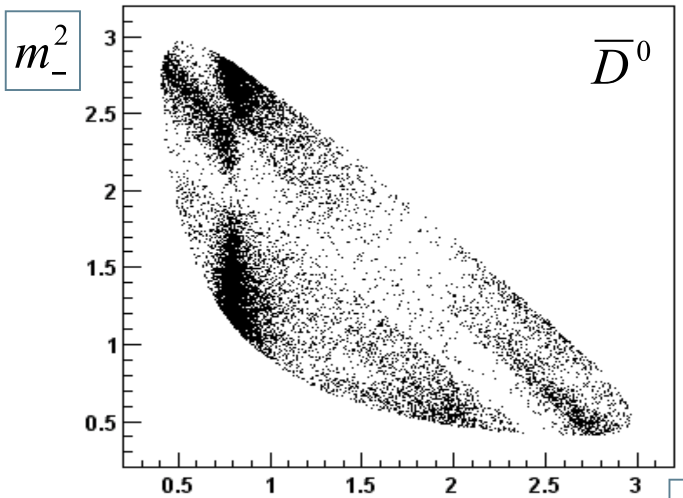
- Use three body Cabibbo allowed decays of the $D^0/\overline{D}^0$
  - $BR(D^0 \rightarrow K^0\pi^+\pi^-)=(5.97\pm0.35)\%$
  - $BR(D^0 \rightarrow K^*\pi)=(3.9\pm0.3)\%$, $BR(D^0 \rightarrow K_s\,\rho)=(1.55^{+0.12}_{-0.16})\%\ldots$
- Large strong phases between the intermediate resonances allow the extraction of r_B, δ and γ by studying the Dalitz distribution of events

$$A^- = f(m_-^2, m_+^2) + r_B e^{i(-\gamma+\delta)} f(m_+^2, m_-^2)$$

$$A^+ = f(m_+^2, m_-^2) + r_B e^{i(\gamma+\delta)} f(m_-^2, m_+^2)$$

where $m_\pm = K_S^0\pi^\pm$ invariant mass

$f(m_\pm^2, m_{\text{m}}^2)$ Dalitz amplitudes



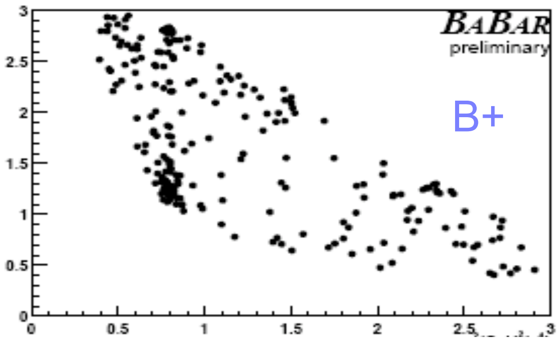
$$|A^-|^2 = |f(m_-^2, m_+^2)|^2 + r_B^2\,|f(m_+^2, m_-^2)|^2 + 2r_B\Re(f(m_+^2, m_-^2)\,f^*(m_-^2, m_+^2)e^{i(-\gamma+\delta)})$$

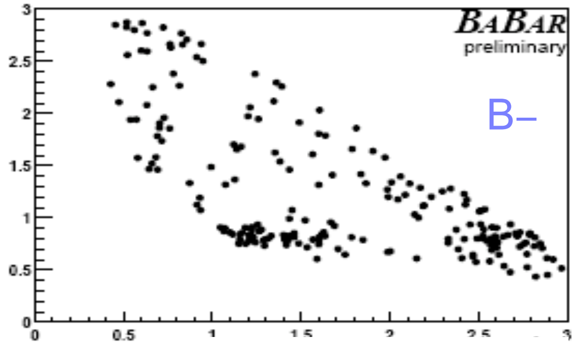
Dalitz model

- B factories consider 16 resonances + non resonant component
- At present dominant systematic error of 11^{o} from model uncertainties
- Scope for improvement:
  - Alternative fit to Dalitz plane with full partial wave analysis of non-resonant component
  - CLEO-C and B factories will improve statistics to measure the Dalitz plot
  - Use model independent binned technique - loss of statistical power
    - CLEO-C correlated data could be used directly in a model independent binned treatment

Measuring γ from B-factories

m_-^2





$m_+^2 = m(K_S^0\pi^+)^2$ $m_+^2 = m(K_S^0\pi^+)^2$

hep-ex/0507101

*D** and *D* combined

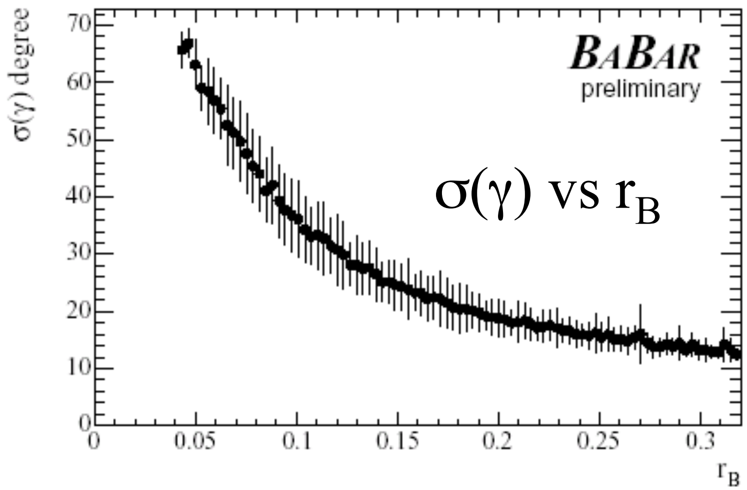
Babar:

γ = **67°±28°±13°±11°**

$r_B = 0.05 \pm 0.11$

Exp. systematic

Dalitz Model error



Belle:

PRD 70, 072003 (2004)

γ = **68°±14°±13°±11°**

$r_B = 0.21 \pm 0.08$

At present typical event yields / experiment ~ 300

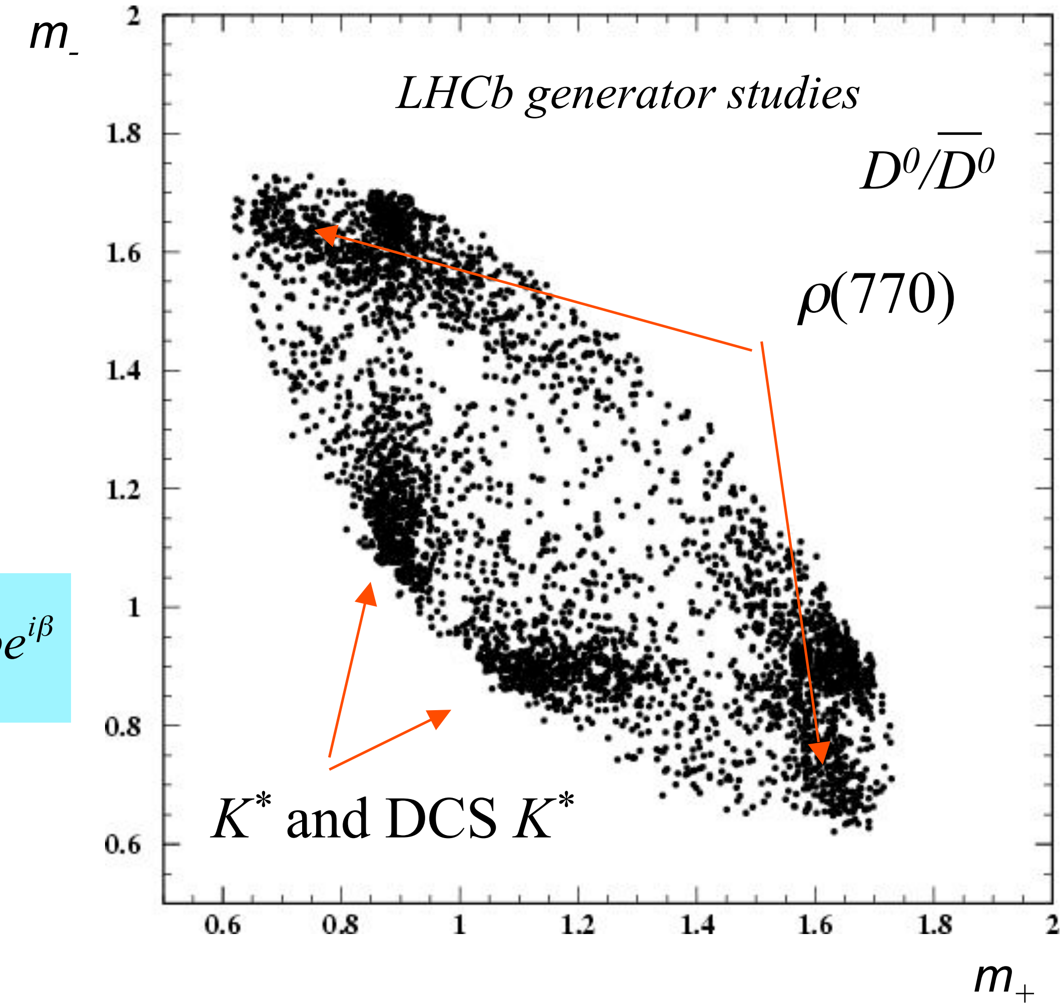
$B^+ \rightarrow D^0(K^0\pi^+\pi^-)K^+$: Dalitz plot

- Regions of the Dalitz plot with the largest interference are most sensitive to γ
- Need good understanding of Dalitz amplitudes
- Use isobar model from Belle/Babar with:

$$f(m_+^2, m_-^2) = \sum_{j=1}^{N} a_j e^{i\alpha_j} A_j(m_+^2, m_-^2) + b e^{i\beta}$$

Breit-Wigner + non-resonant

- B simulated with γ=64.7°, δ=150°, r_b=0.16



Annual yield: $B^+ \rightarrow D^0(K^0\pi^+\pi^-)K^+$

- Acceptance studied with phase space MC

  $\varepsilon_{tot} = 0.10\%$

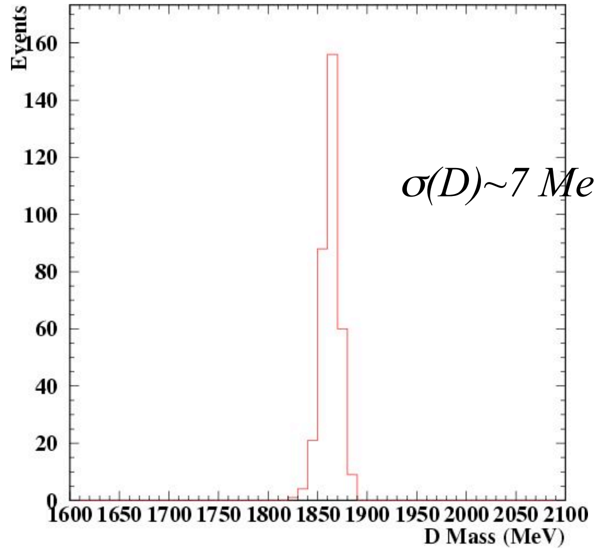
  (selection + L0L1 trigger = 5.8%)

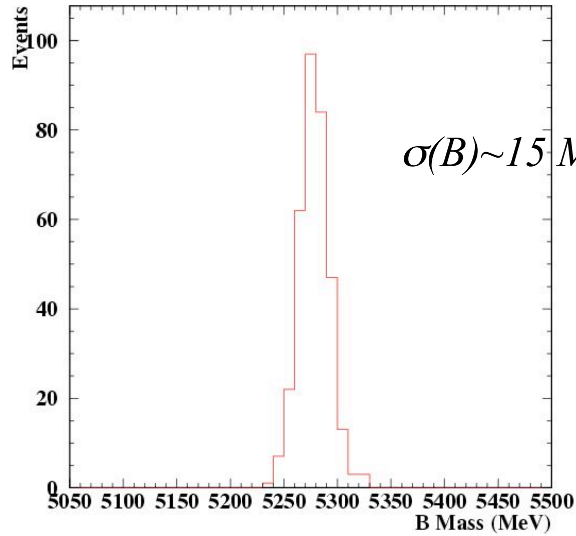
- Luminosity = 2 fb^{-1}

- BR($B^+ \rightarrow D^0(K_s\pi^+\pi^-)K^+) = 7.5 \times 10^{-6}$

- Expected ~6000 events/year not including High Level Trigger efficiency (or > 1300 including it)

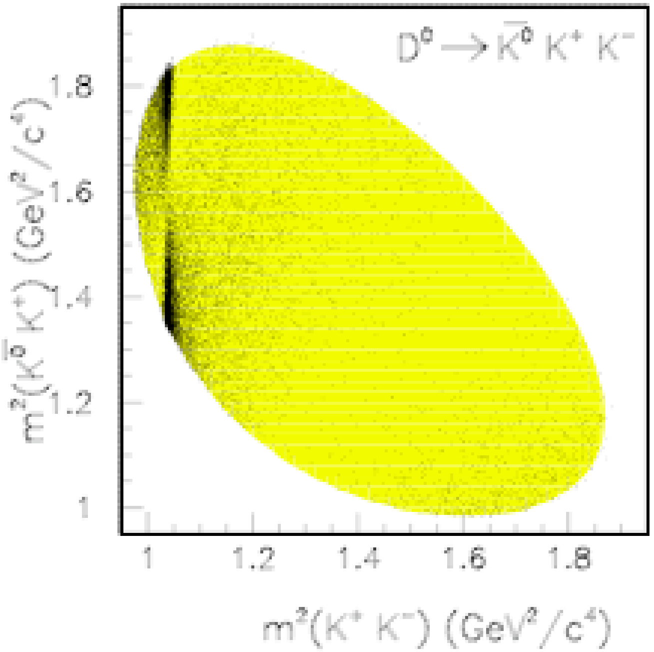
  - 0.5< B/S < 3.2 @ 90%CL





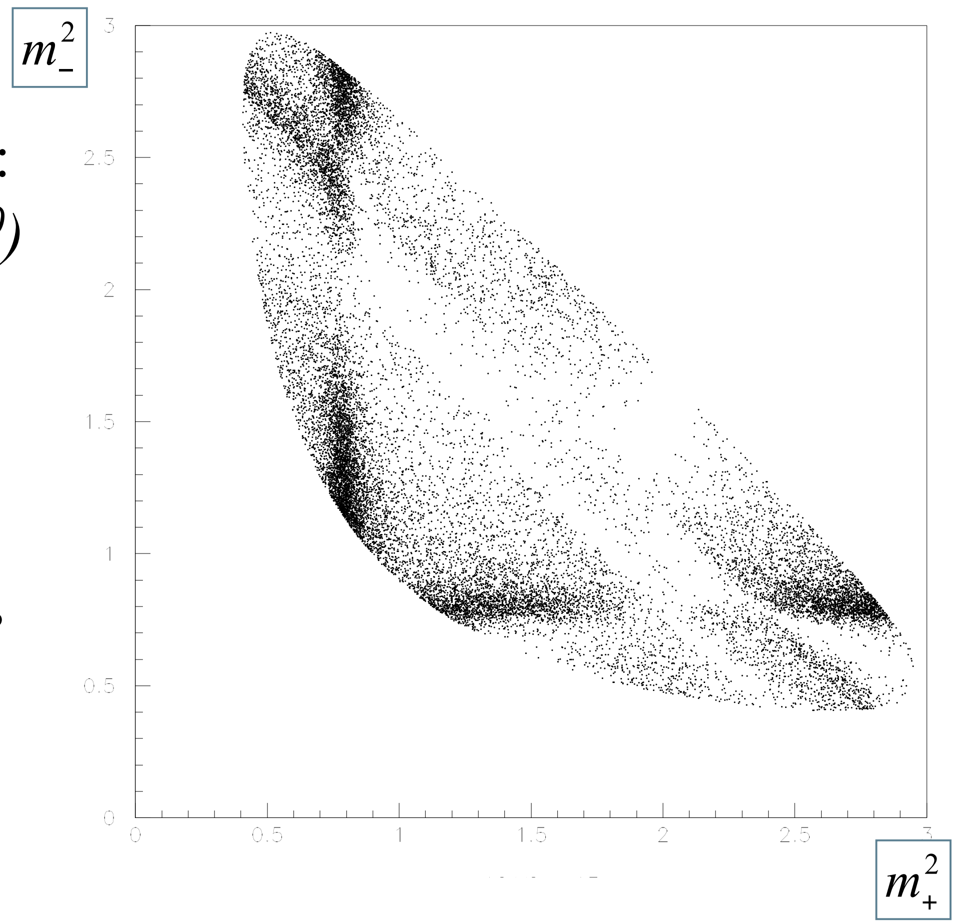
$B^+ \rightarrow D^0(K^0K^+K^-)K^+$

- Same method works for $D^0 \rightarrow K^0K^+K^-$ decay
  - Reduced BR:
    $BR(D^0 \rightarrow K^0K^+K^-) = (1.03 \pm 0.10)\%$
  - But less background because two more particle identification constraints from RICH should substantially reduce background - also narrow phase space
- Acceptance evaluation in progress
- Dalitz model has fewer resonances (ϕ, a_0) but complex threshold effects (Babar hep-ex/0507026)
  - Separate study of sensitivity is necessary



Dalitz: $B^0 \rightarrow D^0(K^0\pi^+\pi^-)\ K^{*0}\ (K^+\pi^-)$

- Same method works as in charged B
  - BF Reduced by factor 10: $BF(B^0 \rightarrow D^0(K^0\pi^+\pi^-)K^{*0})$ *with* $K^{*0} \rightarrow K^+\pi^-$ $= 6.4x\ 10^{-7}$
  - Higher interference (r_b~1)
- Dalitz model imported from Belle; amplitudes and phases of resonances taken from CLEO (hep-ex/0207067)



$B^{\pm} \rightarrow D^{\pm} K$ Conclusions

- ADS method:
  - Candidate for LHCb's most precise measurement of γ
  - Expected annual signal yields (Luminosity = 2 fb^{-1}) :
    - $D(K\pi)K$ - favoured ~ 60k B/S ~ 0.5
      suppressed ~ 2k B/S ~ 0.5
    - $D(KK)K$ ...?
    - $D(K\pi\pi\pi)K$
  - With our present understanding of the background a precision on γ of ~5^o looks feasible with 2fb^{-1} of data
- Dalitz method:
  - Expected annual signal yield ~6000 without High Level Trigger efficiency (to be compared to ~300 at B-factories)
  - $0.5 < B/S < 3.2$ @90% CL
  - Result on the sensitivity to γ will be available within the time scale of this workshop

$B^0 \rightarrow D^0 K^{*0}$ Conclusions

- GLW method:
  - Expected annual signal yields (Luminosity = 2 fb^{-1}) :
    - $D(K^+\pi^-)K^{*0}$ ~ 2.4k B/S >2
    - $D(K^-\pi^+)K^{*0}$ ~ 0.5k B/S>0.3
    - $D^0_{CP}(K^+K^-)K^{*0}$ ~0.6k B/S>0.3
  - $\sigma(\gamma)$~8^o in one year
  - Work ongoing to understand biases introduced by DCS amplitude in D->Kπ
- Dalitz method:
  - Expected annual signal yield < 600 due to BR 10 times lower than the charged one and the presence of one more final state particle
  - Background rejection under investigation
  - Sensitivity to γ in progress